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ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT: TRENDS, NEEDS AND INTERNATIONAL COOPERATION

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ABSTRACT

Environmentally sustainable development is a fundamental concept that must be followed to ensure the oceans and their resources are utilized and conserved in an environmentally acceptable manner to preserve and maintain the quality of life for present and future generations. The environment is being stressed in many ways, while the pace of development accelerates to meet societal needs.

The global environment is constantly changing due to relatively slow natural processes punctuated by occasional natural disasters, and human-induced impacts that appear to be causing faster change. There is a great concern about: the state of the global environment; the consequences of its continuing degradation; and the need for environmentally sustainable development.

World population has been growing exponentially over the last 40 years and is expected to almost double over the next 40 years, from over 5 billion to about 9 billion. This steady increase equates to: less land per person; a greater need for food, energy, and material resources; and a significant impact on our environment. Rapid technological and economic development has contributed to the degradation of the global environment; provides the technological means for monitoring the environment; and provides the capability and potential for restoring the environment.

This paper covers the topics of global warming, ozone depletion, marine pollution, resource degradation and depletion, natural hazards, global environmental change, and ocean space utilization. It briefly mentions the causes and effects and then describes some potential solutions through the application of advanced technology to: monitor the environment; help restore the environment; and use the oceans and their resources in harmony with the environment.

Some of the ocean-oriented activities or projects needed for environmentally sustainable development include: global ocean observation networks to monitor global change; data collection; analysis and strategic assessment techniques; alternate nonpolluting inexhaustible ocean energy sources, coupled with aquaculture systems; artificial upwelling; techniques for sequestering CO_2; ocean incineration techniques; and seaward extension using artificial islands and floating cities. These research and development projects will play a very important role in restoring the global environment and safely developing their vast resources, while ensuring conservation and resource renewability for future generations.

1. INTRODUCTION

The global environment is constantly changing due to relatively slow natural processes punctuated by occasional natural disasters, and human-induced impacts that appear to be causing faster change. There is great concern about the state of the global environment, the consequences of its continuing degradation, and the need for redirection toward environmentally sustainable development. The call being heard around the world is for: immediate action to halt further degradation; restoration of the damaged environment; and the development and utilization of global resources in harmony with the global environment. The bottom line is to improve or at least maintain the quality of life for developed nations, and to improve the quality for developing nations. This must be done in the face of a rapidly growing population that is consuming and disposing more of the remaining resources.

World population has been growing exponentially over the last 40 years and is expected to almost double over the next 40 years, from over 5 billion to about 9 billion. This steady increase equates to: less land per person; a greater need for food, energy, and material resources; and a significant impact on our environment. In the process of continued development and utilization of resources to meet the burgeoning needs, considerable attention must be given to protecting the environment and conserving resources for future use by us and following generations.

Rapid technological and economic development has contributed to the degradation of the global environment, provides the technological means for monitoring the environment, and provides the capability and potential for restoring the environment. By definition, the global environment involves the entire earth, ocean, and atmosphere, which are intrinsically intercoupled. This paper will focus on environmentally sustainable development, mainly from the perspective of the oceans which: cover almost three-quarters of the global surface; provide a major portion of our untapped resources; and have a major impact on our global environment. This paper covers the topics of global warming, ozone depletion, marine pollution, resource degradation and depletion, natural hazards, global environmental change, and ocean space utilization. It briefly mentions the causes and effects and then describes some potential solutions through the application of advanced technology to: monitor the environment; help restore the environment; and use the oceans and their resources in harmony with the environment.

2. GLOBAL WARMING

Causes and Effects

The phenomenon of global warming over the past century has been attributed to atmospheric accumulation of greenhouse gases, such as carbon dioxide and methane, which act like a blanket to trap the sun's radiant heat. Greenhouse gases are produced by all forms of combustion, especially by automobiles, power generation, and the burning of wood in clearing forested land such as the Amazon rain forest. The environment's ability to assimilate carbon dioxide is being reduced because expanding urban development, deforestation, and destruction of rain forests increase the losses of trees and vegetation —the natural assimilators of carbon dioxide. The processes and capacity of our oceans to assimilate or release carbon dioxide is not well known at this time. Though exact figures cannot be predicted, the general consensus is that global warming will increase and produce deleterious effects impacting agriculture, causing sea-level rise, and affecting quality of life while society adjusts to its effects.

One consensus of researchers agrees that the Earth on average has warmed about 1°F over the past century, and if CO_2 levels double by the middle of the next century, global average temperatures may increase several more degrees. The resultant warming would no be uniform over the Earth. It would be least in the tropics and greatest at the poles where it would melt some of the polar ice caps. The melted ice, most of which is now on land, and the thermal expansion of the oceans would cause global sea levels to rise. The exact magnitude and timing of worldwide warming and the sea-level rise continue to de debated by scientists.

The 1980s were the warmest decade in the last century and 1990 was one of the warmest years on record. The 1988 midwestern U.S. drought is a recent example of the effects of a warm, dry summer that affected agriculture productivity, and barges were stranded on the Mississippi River by all-time low water levels. Warming of the seas has already caused environmental degradation of coral reefs around the world. As the sea warms up, the coral polyps that build the reefs with their skeletal remains stop feeding on micro-algae and become weak and die; then, the reefs lose their red, yellow, and golden hues, leaving the coral with a bleached look. These reefs can serve as early warning indicators of global warming of the seas.

Over the past 50 years, global sea levels have been rising at about 3.0 millimeters a year (three times the rate of the previous 50 years). If this trend continues or possibly escalates, the sea levels could rise as much as 30 to 60 cm by the middle of the 21st century, flooding some coastal cities and villages. This will create a concern in designing and constructing homes, buildings, ports, and harbors for future coastal communities.

Solutions

Ocean science and technology can play a vital role in providing: a wide variety of atmospheric and ocean measurement systems and large-scale networks to monitor the effects of global warming; conservation measures to reduce consumption of fossil fuels; means for reducing CO_2 emissions; alternate fuels for transportation; alternate energy sources for supplying electrical power; a means for redeeming CO_2; and new water supplies to offset scarcity due to warming. Each of these will be discussed below.

Environmental Monitoring

Environmental monitoring for acquiring data and assessing the effects of global warming involves making synoptic and temporal environmental measurements of the atmosphere, ocean, and over land on a global scale over a long term. There are many programs worldwide, involving international cooperation, that are concerned with monitoring and measuring parameters pertaining to global warming. This section will briefly cover some ongoing activities in atmospheric measurements of greenhouse gases and global sea-level rise. The all-encompassing U. S. Global Change Research Program will be covered in a separate section.

At NOAA's Climate Monitoring Laboratory in Boulder, Colorado, CO_2 concentrations were reported at an average rate of 0.7 parts per million (ppm) per year in the 1960s; 1.5 ppm in the early 1980s; and 1.7 ppm in the late 1980s. One calculation estimates that a 1 ppm increase would be the result of over 2 billion tons of carbon in the air. Other greenhouse gases are much less common, though some are more powerful in their effects. Methane concentrations have been rising about 12 parts per billion per year and nitrous oxide at a rate of about 0.7 parts per billion per year.

Since 1957, CO_2 measurements made at Hawaii's Mauna Loa Climate Observatory, at an altitude of about 11,000 feet, revealed a steady increase in atmospheric CO_2. To date, the change from 290 parts per million in 1880 to 352 parts per million in 1989 represents more than a 20% increase over a century.

Regarding sea-level rise, a global sea-level measurement network is available for measuring absolute sea-level rise, rather than sea-level rise relative to a land-based reference which may not be stable over time. This network currently consists of about 16 stations worldwide. Very Long Baseline Interferometry (VLBI) techniques are used to obtain position accuracies of about 1 cm. This is accomplished by having two stations, separated about 10,000 kilometers (km) apart, simultaneously tracking an extra galactic source sich as a quasar. Each station receives the same radio signals, but since each station is at a different geodetic location, the return signal is slightly displaced in time such that a phase difference error occurs. Since the distance between stations is known and triangulation on a quasar is obtained, any land instability due to an earthquake or land subsidence is known within a 1 cm deviation.

NOAA's next generation water level measurement gages can be referenced to a VLBI geodetic fix for an absolute water-level measurement accuracy of 1 cm or less. Similarly, the Global Positioning Satellite (GPS) system can also be tied into a geodetically accurate system. GPS will consist of about 22 satellites by 1992 and will provide global coverage. Presently, there are 26 gages in the U.S. and about 16 others in the Atlantic and Pacific that are coupled with VLBI and the GPS system to measure sea-level rise. These measurements over time will enable better sea-level predictions to plan for future coastal development and protection against flooding.

As mentioned earlier, the environmental impact of sea warming can be monitored by observing degradation of coral reefs, as was noted on a global scale at such places as Florida, Puerto Rico, Bermuda, Hawaii, and Okinawa. This phenomenon has already occurred three times in the last decade.

Conservation of Energy

Conservation can reduce the amount of fossil fuel required to meet societal needs. Studies have indicated that as much as 50% of consumed energy is wasted because of leakages in heating and cooling buildings and homes. Also, about 25% of the energy consumed is wasted on the inefficiencies and excessive power of combustion engines in various forms of transportation. These are significant figures; however, it is not the purpose of this paper to cover building construction standards or combustion engine design. Invoking building standards as a matter of governmental policy can result in major reductions in energy needs. In the area of marine transportation, recent developments in automated sail-rigged ships, aerodynamically streamlined superstructures, and optimal hull-shape designs can reduce energy needs up to 50%. Less fuel combustion due to conservation not only reduces CO_2 emissions, but greatly improves operating efficiency and reduced costs.

Reduction of Co_2 Emissions

Conservation obviously reduces the amount of fossil fuel required and CO_2 emitted. There is still a need to improve the means for minimizing CO_2 by "scrubbing" emissions before they reach the atmosphere and using cleaner fuels.

Alternate Fuels

Alternate fuels that greatly reduce harmful emissions have been proposed and experimentally demonstrated. Fuels such as natural gas and gasohol can be adapted to present engines. Hydrogen is another option that has been sucessfully demonstrated as a nonpolluting fuel; however, nonpolluting energy sources such as hydroelectric power or solar-derived energy sources must be used as the primary source for generating hydrogen via electrolysis techniques. Converting hydrogen fuel enables solar-derived energy sources to have an energy storage capacibility for excess power. A world economy based on hydrogen fuel has been a long-standing objective of the International Association for Hydrogen Energy.

Alternate Energy Sources

At present, the main sources of energy are the combustion of hydrocarbons, followed by nuclear power. There appears to be sufficient oil and gas reserves on land and offshore to supply energy for about 40 years and coal reserves can extend to the 22nd Century. However, to reduce CO_2 emissions, hydrocarbon use should be cleaned up and efficiently phased out in favor of nonpolluting alternate energy sources. Onehundred percent safe nuclear power would be a good alternative, but society has not been receptive to nuclear power. For example, the rate of nuclear plant development in the 1980s for the U.S. was cut in half from the 1970s. At present, the percentage of nuclear power usage for individual countries' ranges from 16% in the U.S., to 23% in Japan, to 65% in France. The general slowdown is mainly due to public concern about environmental hazards, the remote possibilities of catastrophic failure, and the increasing costs associated with installing a new plant. The "not-in-my-backyard" syndrome is still a major opposing factor. Because of its potential, nuclear power sould be reconsidered with safety measures that may be more acceptable to the public. Nuclear fusion technology may provide a major breakthrough for safe nuclear power well into the 21st Century. However, the present state-of-the-art is limited to about 2 megawatts for 2 seconds.

Solar energy is an inexhaustible, nonpolluting source that has great potential as an alternate energy source for the future. It can be processed directly through thermal and photovoltaic methods, as is currently being applied to solar-heated and powered homes. Solar energy can also be processed indirectly by converting the dynamic motion of winds, waves, and currents induced by solar winds; converting ocean thermal and salinity gradients; and converting biomass energy derived through photosynthesis.

At present, the most promising area of solar-derived ocean energy development is in ocean thermal energy conversion (OTEC). An offshore floating OTEC facility can transmit electrical energy to shore by cable or can use the energy offshore for various purposes—desalinization of water, ammonia production, hydrogen liquefaction, and energy-intensive industries such as alumina processing. The combination of a nearshore or land-based OTEC plant with an aquaculture or biomass facility and a desalinization plant is a compatible arrangement that can provide multiple benefits. Cold, deep water is a valuable resource rich in nutrients and has been successfully used in aquaculture and biomass production.

Over the past 15 years, the U.S. Department of Energy has spent over $250 million on OTEC research and development. Japan and France have also spent substantial sums. Considerable progress has been made towards demonstrating technical and economic feasibility of small scale (less than 5 MWs), closed-cycle, shelf-mounted OTEC plants. Recent results of heat-exchanger research have brought small scale OTEC plants close to economic competitiveness with a fossil fuel plant. This research showed that zinc clad aluminum-plate type heat exchanges provided the desired heat transfer characteristics at a competitive cost that could translate into a 3-megawatt, shelf-mounted OTEC plant for under $5,000 per KW installed. There are many applications for under 5 MW plants in the island marketplace. This small market size will enable OTEC technology to mature and scale up to larger-scale plants. The key to commercializing OTEC is to build the first one and keep iterating the design with improvements in performance and cost.

Another potential benefit of OTEC is the possibility of CO_2 redemption as a result of stimulating the photosynthesis process by pumping up and discharging deep, cold water rich in nutrients. In this photocynthesis process, the resultant photoplankton absorbs CO_2 and eventually sinks to the bottom with the absorbed carbon, thus providing for CO_2 redemption from the atmosphere. The increased primary productivity will also contribute to the production of dimethyl sulfide (DMS), which is released into the air and oxidized into sulfate particles to form cloud condensate nuclei and increase cloud albedo. This, in turn, reflects sunlight to lessen the heating effects of solar radiation. Hundreds of OTEC "upwelling" systems may result in some offsetting of the greenhouse effect not only by CO_2 redemption, but also by displacing the need for fossil-fueled energy systems.

Wave energy is another solar-derived, inexhaustible, nonpolluting energy source. Japan, the United Kingdom, and Norway are leaders in wave energy research and development, and have sites with substantial wave energy density. For example, on the west coast of the United Kingdom, a long coastal area averages about 50 kilowatts (KW) per meter of wave front. In Japan, a number of small-scale systems are under evaluation. Most of these systems use the oscillating water column, especially the Wells type. The most well known is the KAIMEI floating vessel containing about 10 oscillating water columns. In the Pacific, two commercial wave energy systems are being constructed by the Norwegian company NORWAVE A.S.: one system in Java and the other in Tasmania. They both use the Tapered Channel (TAPCHAN) techniques, each providing about 1.5 megawatts of power. Typically, a tapered channel is carved out of a rocky coastal area, using shaped charges, if necessary. The taper can handle a wide spectrum of wave lengths efficiently. As a wave passes through the tapered channel, its wave height is gradually increased as the channel narrows. The wave then spills over into a reservoir where it is stored and subsequently passes through a low-head Kaplan water turbine to generate electricity. The construction costs of these NORWAVE systems equate to about $ 2,500 per kilowatt hour. These commercial systems are expected to produce power at rates of about 5 to 10 cents per kilowatt hour.

Tidal energy is generated by collecting rising tidal water behind a barrier and then releasing it on ebb tide through turbines to generate electricity. A number of operating tidal power plants exist worldwide, including USSR, Canada, and France. The French plant, at the Rance River, has operated successfully since 1968, and generates 240 MW. A tidal power plant has been proposed across the Severn Estuary between England and Wales, where the mean spring tidal swing is about 13 meters with an estimated total regional capacity of 7200 MW. Ideal sites require large water volumes with large swings in tidal levels and limited usage by other ocean enterprises at that location. Tidal power plants at sites meeting this general criteria can produce electric power at competitive rates.

In the U.S., current energy conversion techniques have been examined for harnessing the Gulf Stream off the Florida coast. This stream carries 30 million cubic meters of water per second, more than 50 times the total flow in all of the world's freshwater rivers; the surface velocity sometimes exceeds 2.5 meters per second. The extractable power is about 2,000 watts per square meter and would, therefore, require extremely large, slow-rotating blade turbines operating like windmills. The total energy of this Florida current is estimated to be about 25,000 megawatts (MWs), and extracting about 4% is not expected to disrupt climatic conditions. This would be 1,000 MWs or the equivalent of one nuclear power plant. The amount of the current energy resource is not as abundant as the ocean thermal resource. Hence, development of technology for constructing and installing only a few systems must be considered in a cost-benefit analysis.

Salinity gradients provide an enormous resource worldwide, comparable to ocean thermal gradients. The present major limitation is the inadequacy of osmotic membranes. Since sea-based salinity gradient conversion systems must be near freshwater sources such as estuaries, they could present a constraint to navigation and other uses in such areas.

Solar and solar-derived ocean energy is ideally suited for the 21st Century because it is an abundant, inexhaustible, nonpolluting resource. It can be converted directly for electric power and stored by conversion to hydrogen fuel; and as in the case of OTEC, provide additional products such as nutrients for aquaculture and fresh water.

Sequestering Co_2 from the Atmosphere

The possibilities of sequestering CO_2 from the atmosphere via stimulating the photosynthesis process due to discharging nutrient-rich, cold water in OTEC operations have been noted. An artificial upwelling system (covered later in Section 5) used to enhance coastal fisheries also provides the possibility of sequestering CO_2. R. Ravelle, University of California, proposes fertilizing the seas at high latitudes with phosphates to accelerate photosynthesis; and M. McElroy, Harvard, suggests orbiting reflectors to beam extra sunlight to the arctic and antarctic seas.

Another concept pertains to using dynamic oxidation reduction of iron in seawater. The photosynthesis process in the marine food chain is stimulated by nutrients such as phosphates and nitrates. Recent studies have shown that the addition of iron to some regions of the ocean can result in enhanced organic production and fixation of CO_2 into organic carbon forms. In 1990, a 30-day field experiment in the Pacific at 140° W, sponsored by the Office of Naval Research, supported the hypothesis that photochemically induced iron redox cycling is integral to this process. Dynamic oxidation-reduction cycling of iron involves microbial activity and photochemical reactions. Without these dynamic processes, iron becomes unreactive and bound in solid phases.

Another concept, with some activity on an international scale, is reforestation to restore some of the losses due to deforestation mentioned earlier. This would restore a natural means of assimilating CO_2 from the atmosphere. Restoration of coastal wetlands based on a no-net-loss policy also provides for aquatic vegetation that engages in natural CO_2 assimilation. A concept of no-net loss of forest in urban development and industrial activities should be adopted on an international scale not only for CO_2 sequestering, but for sustaining a more natural environment more acceptable to human-kind. G. Woodwell, Woods Hole Oceanographic Institution, calculated that 720,000 square miles of new forest (4.5 times the area of California) would be needed to remove one billion tons of CO_2 annually (1/3 of the problem).

Based on this calculation, spacing of 5 meters between trees would be equivalent to every human being on Earth planting four trees.

3. OZONE DEPLETION

Another alarming concern that can have a steadily increasing impact on the global environment is the creation of a hole in the upper atmosphere's protective thin layer of ozone gas. This layer protects all life from harmful ultraviolet radiations. The "ozone hole" is formed when ozone is destroyed by chemical reaction with chlorine and other chemicals, including man-made products containing chlorofluorocarbons (CFCs). The hole allows an increased level of ultraviolet rays to pass, leading to damage by overexposing phytoplankton which is the basis of the food chain for marine life. Because of the ozone hole's shifting occurrence about the South Pole, ultraviolet overexposure in parts of Australia is a major concern. Similar shifts around the North Pole could have a serious impact in the northernmost countries in the Northern Hemisphere. Seasonal creation of the ozone hole over the South Pole is as severe in 1991 as it was in 1987, 1989, and 1990 —the worst years on record.

The accumulated emissions of CFCs used in products such as aerosol cans, refrigeration, and air conditioners have caused the ozone depletion. Reducing further degradation requires greatly reducing CFCs used and finding replacement substances. In the meantime, scientific research programs continue to monitor the atmosphere to determine status and trends, to better understand the interactive processes, and to determine if the effects of causing the ozone hole can be reversed.

4. MARINE POLLUTION

Causes and Effects

Almost three-quarters of the global surface is water. Because of its vastness, as well as its ability to assimilate and diffuse the effects of waste, the ocean has long been used as man's repository for intended and accidental waste disposal. However, finite limits are being reached in many coastal areas, as highlighted by beach closings, prohibitions on shellfishing, habitat losses, and health warnings to seafood consumers. Many coastal regions around the world, especially near major population centers, have reached critical stages of marine pollution due to: sewer outfalls, ocean dumping, land runoff, shipping discharges, and plastic debris from marine recreational activities and marine vessels.

In addition, industrial waste and effluents are being discharged in coastal waters, and in rivers and streams that terminate in coastal estuaries. Hazardous material spills, especially those that occur in coastal waters and within the Exclusive Economic Zone (EEZ), are a major polluting concern. Major oil spills such as the EXXON VALDEZ (spilling 11 million gallons) and the AMOCO CADIZ (spilling 60 million gallons) provide documented results of the damaging effects on marine life, marine habitat, beaches, wetlands, and on the economy and quality of life in coastal communities.

The greatest concern is for the disposal of high-level and low-level radioactive waste. International agreements prevent ocean disposal of high-level radioactive waste but have not stopped disposal of low-level waste. The effects of radioactive waste entering the ocean food chain and the ocean's inherent transport mechanisms would have wide-ranging implications, depending on the radioactive levels and half-life expectancies.

Power plants and vehicles release gaseous emissions that are transported by clouds and winds aloft and eventually settle down as acid rain to cause terrestrial and aquatic damage. Emitted sulfur and nitrogen oxides react with other compounds in the atmosphere to form acidic particles. The acid kills aquatic life in streams, lakes, and estuaries; pollutes water supplies; destroys terrestrial foliage, acidifies soils; and damages buildings and materials. Power plants are the largest source of sulfur pollution and the second largest source of nitrogen oxides; vehicles are the largest source of nitrogen oxides.

Solutions

Science and technology have vital roles in providing: instrumentation and techniques to measure, monitor, and analyze pollutants and their detrimental effects; a means to prevent pollution or reduce its effects; and options for transporting and disposing waste. Each of these is discussed below.

Monitoring and Analysis

A wide variety of marine instrumentation systems is used to sample, measure, and analyze water quality, sediments, and marine life for pollutants. A major program underway at NOAA over the past 6 years is the Status and Trends Program. This program involves sampling bottom fish, shellfish, and sediments at about 300 sites in coastal waters around the United States; making laboratory measurements of over 70 chemical contaminants in sediments, fish livers, and bivalves; and analyzing annual measurements for year-to-year comparisons to determine the status and trends in pollutant levels. Every year, 10% of the samples are cryogenically stored at -150°C to permit retrospective anaylisis as new analytical techniques become available. Based on 6 years of measurements, the highest concentrations of both trace elements and organic contaminants were found near major coastal cities of Boston, New York, San Diego, Los Angeles, and Seattle. Except for a few sites around Florida, contaminant levels at sites in the Gulf of Mexico and southeastern U.S. were relatively low. Even in high concentration areas, sampling must be conducted at "hot spots" near waste discharge sites or industrial zones to find concentrations that could cause harmful biological effects.

NOAA's Strategic Assessment Program enables multi-users of the coastal environment to make informed decisions for the wise use of the ocean and its resources in harmony with the environment. This program has collected, compiled, processed, and analyzed vast amounts of information on everything in and about the coastal ocean, including: oceanographic characteristics, available resources, industrial and shipping activities, and ocean disposal sites. This information is recorded in atlases for most of the U.S. EEZ. To facilitate entry and access, data and information is electronically-stored and accessed using Geographical Information System (GIS) techniques; and then processed, analyzed and printed out for hard copy dissemination. Desktop information systems are used to enable resource managers and researchers to easily access the vast body of information available. These systems include: CMAS, a computer mapping and analysis system providing spatial and temporal distributions of coastal ocean living resources; COMPASS, a coastal ocean management and assessment system to access coastal resource information and provide summary analyses in graphic or mapped formats; and GeoCOAST, a coastal ocean geographical information system to address environmental quality issues for management and protection of the coastal area, including the EEZ.

NOAA's Hazardous Materials Response Program provides scientific support coordination to the U.S. Coast Guard for all hazardous material spills. This includes critical information on: spill trajectory projections, chemical hazard analyses, and sensitivity assessments of the marine and estuarine environments to spills. Over the last decade, this program responded to 2,000 spills, the largest being the EXXON VALDEZ. A desktop computer system, using a Computer-Aided Management and Emergency Operations (CAMEO) program, enables emergency planners and first responders to handle chemical accidents. The program is so successful that over 4,000 systems are now being used by local fire departments, state hazardous material departments, and port and harbor authorities.

One of the areas needing significant engineering and technology improvement in environmental measurements and monitoring is to provide rapid, underway, in-situ, real-time, sampling and/or measurements, analysis, mapping, and storage of processed data. The technology is available and requires a comprehensive effort in system design, integration and at-sea evaluations; however, this type of development requires funding over a number of years to achieve a commercial product. A NOAA-sponsored project, undertaken by the University of Georgia, uses a small towed device to perform in-situ superficial sediment sampling, followed by real-time X-ray florescence analysis and mapping of processed data. This project, initiated 10 years ago, is still undergoing improvement in the course of experimental usage. The next phase will involve incorporating sensors to enable in-situ chemical measurements. Another improvement for this system would be to add a fast neutron gun to irradiate in-situ samples and analyze back-scattered spectrum for constituent elements.

In the future, autonomous undersea vehicles (AUVs) can have a major role in performing in-situ, real-time environmental measurements covering a large coastal area such as an estuary. The AUV is ideal for performing long-duration repetitive measurements and sampling over a given track and for periodically being used over the same track to make comparisons. Several hundred million dollars are now being spent, mainly in the U.S., Japan, and the European Economic Community, to advance the development of AUVs to where they can eventually be used reliably for commercial applications.

Pollution Prevention

The most effective solution to marine pollution, especially in the long term, is prevention. The old adage, "an ounce of prevention is worth a pound of cure," really applies and equates into substantial economic savings and environmental benefits. Existing legislated programs at NOAA promote prevention such as coastal zone management, marine sanctuaries, and the Estuarine Research Reserve that enables acquiring important wetlands.

Waste material should be considered as a recoverable resource that can be separated and recycled for further use in other product forms. Profit-making recycling systems are in operation, especially in Japan. Automated sorting and recycling systems are now in use and show promise of cost-effectiveness. However, what is being done in recycling is insignificant compared to what needs to be done.

Landfills, accepting municipal waste from major cities, are running out of space, and other options such as incineration are needed. The public finds fault with many U.S. incinerators that still belch out toxic residues. Incineration technology is available to ensure full compliance with air-quality standards. At present, the U.S. supports an international ban on ocean incineration. Assuming ocean incineration can meet environmental health standards, the public may tend to favor this method in the future and avoid the "not-in-my-backyard" syndrome.

Growing international restrictions on deep-sea disposal and state government opposition to near-coastal dumpling presently leaves the EEZ as the remaining ocean region for the possible disposal of certain kinds of waste such as dredged material and some forms of municipal waste. The seabed of the EEZ should be considered along with land-based alternatives with a view to selecting the most environmentally sound solution. Surveys of the EEZ, including information on habitat of living resources, are needed to locate suitable potential sites for specific classes of wastes. Comprehensive studies with due regard for interactions between overlying water and sediments will be necessary. Sub-seabed disposal of low-level radioactive waste is another option being considered. For example, seabed areas outside the EEZ, in the mid-Pacific, have been geologically stable for millions of years. This is an important factor when considering radioactive materials with half-lives in the tens of thousands of years. Should the international scientific community decide that such options are viable and acceptable, this will require special marine facilities for transporting and making dep ocean sub-seabed deposits in special containers that can safely ensure containment, e.g., shielded and vitreous-lined housings. Until alternate solutions are proven viable, radioactive waste is being stored on land.

Major oil spills, due to tanker collisions and groundings, mainly involve human error and technological limitations. To optimize navigation capabilities such as radar, transponders, gyros, Fathometers, communication satellite receivers, computers, and electronic chart displays, technology is available in automated system configurations and vessel traffic systems. It is mainly a matter of economics and implementation. Using this technology and international navigating rules should allow ships to avoid accidents, but equipment reliability and human error will always be prevalent.

Regarding the integrity of present tankers to survive groundings and collisions, studies have favored double-hull designs with an outer hull to absorb damage and an inner hull to ensure containment. U.S. legislation, enacted in 1990, requires double hulls on all new tankers and all tankers to have double hulls within 20 years. At present, the American Petroleum Institute estimates that 150 U.S. tankers have single hulls, 30 have double bottoms, and 10 have double hulls. Double-hull construction is underway on new tankers for the U. S. and Japan.

Regarding waste management practices on ships, the U. S. Navy has developed and installed waste compactors to accept and efficiently store solid waste matter for later disposal ashore. U. S. Coast Guard regulations now prevent disposing plastic items at sea.

Restoration

To provide restoration of damages, NOAA operates a Damage Assessment & Restoration Center to determine the extent of damage-associated costs for compensation; and to use the funds for restoration. For cleanup operations after the EXXON VALDEZ spill, Exxon indicated that they already spent $2 billion on cleanup activities. This year, a court settlement of $1 billion has been declared for continued restoration.

Bioremediation is a technique using bacterial substances to act as organic catalysts to initiate chemical reactions that break down the hydrocarbon chains. Since crude oil is a naturally occurring material, bacterial species have evolved to use it as food. This process has previously been used in water treatment and sewage disposal. More sophisticated cultured bacterial products to clean up oil spills are being applied and evaluated. Studies are needed to: assess any toxic side effects of any additives (nutrients, surfactants, emulsifiers, and so forth) used to stimulate microbial growth; compare the effectiveness of lab-cultured microorganisms versus natural species; and determine the effectiveness and safety of genetically-engineered microorganisms.

5. RESOURCE DEGRADATION AND DEPLETION

Besides global warming, ozone depletion, acid rain, and marine pollution, other factors degrading the environment and depleting resources are present. These include coastal erosion, subsidence, loss of wetlands and estuaries due to natural causes and overdevelopment, and depletion of fishery stocks due to overfishing and poor management. Erosion also increases the vulnerability of coastal developments to flood damage during hurricanes and severe storms.

Overdeveloping coastal areas and reducing natural barriers and buffers created by wetland vegetation such as mangroves, sea grasses, and other aquatic vegetation have caused serious erosion and damage to valuable coastal properties and resources. Coastal wetlands play a vital role in providing marine habitat and contributing to the complex life cycles of a myriad of interrelated marine life that are part of the overall coastal estuary and fishery food chains. Coastal wetlands throughout the world are being lost due to natural processes and man-induced causes associated with development and human activities. In the U.S., new regulatory policies have resulted to ensure no net loss of wetlands due to future development or natural causes. However, experience in creating wetlands on deposited dredged materials is still primitive.

In the U.S., Florida and Louisiana account for about 49% of the coastal wetlands and most of the present losses are in Louisiana. The rate of loss in Louisiana has accelerated from about 5 square miles per year to about 50 square miles per year. This is equivalent to losing 1% of the remaining wetlands per year. In Louisiana, the extensive wetland system has been greatly altered by the construction of many canals, especially large canals for access to oil and gas wells, laying pipelines, and navigation. This has resulted in significant wetland loss and further damage by saltwater intrusion into the canals. A variety of engineering approaches have been pursued or proposed to slow the rate of wetland loss. One approach is to impound sections of wetland by small dikes and regulate water by weirs. This also reduces saltwater intrusion and promotes submerged aquatic vegetation growth. Another is to backfill canals no longer being used and to create wetlands using material excavated from canal dredging. The organic content of the dredged material and soil elevation is important in creating aquatic vegetation.

If environmental assets were considered in our accounting system, then perhaps economic forces could be used to preserve the environment. A healthy economy can only survive in coexistence with a healthy ecology. However, the true value of a healthy ecology is not factôred into gross-national product (GNP). For example, one acre of swampland may have a market value of $500, but its true worth to society must be measured by its contributions to such functions as water filtering, commercial fishing, trapping, recreation, and storm protection. These value-added ecological functions can raise the economic worth to society 5 to 10 times its market worth as swampland real estate. Better methods are needed to place values on such ecological functions and to provide policies to translate these values into incentives that preserve them.

Degradation and depletion of fishery resources due to marine pollution and loss of habitat is a serious problem facing the increasing world population and its growing dependence on fish products for protein. Marine pollution in coastal estuaries and the coastal ocean has affected the quality and abundance of the entire fishery food chain. In the U.S., coastal areas are monitored and assessed regarding water quality and safety of fish products. Many areas have been designated as unfit for harvesting fish or shellfish products. In the past 5 years, approved acreage for harvesting shellfish has decreased from 68% to 65%.

U.S. legislation is being considered to establish a comprehensive safety and quality assurance program for fish and fish products. Its purpose is to reduce problems associated with eating seafood and to encourage the acceptance of quality U.S. products in foreign and domestic markets. Standards would be established for maximum allowable contaminant levels; procedures for sanitation and quality control of seafood processing; product standards for product identification and composition; and requirements for seafood growing and harvesting areas.

Some solutions to marine pollution and loss of wetlands were discussed earlier. In coastal areas restored through corrective actions and in areas still fit for fisheries development, fisheries management will continue to play a key role in assuring that maximum sustainable yields are not exceeded and that future stocks can be expected to be abundant and healthy. Many cases exist worldwide where fishery stocks have been depleted due to overfishing and where maximum sustainable yields have been reached. To offset these problems, other means are needed to increase abundance.

The construction and installation of artificial reefs that provide new habitats is one method that continues to be used. In fact, offshore platforms, especially in the shallower waters of the Gulf of Mexico, have provided some degree of habitat that has attracted marine life. Another method to enhance fishery stocks is through open ocean ranching in estuaries and protected coastal areas. This entails providing large, fenced-off areas and artificial habitats to contain and rear fish stocks. In Norway, for example, offshore locations are sought where fences can be erected between natural barriers such as small islands or around coves, thus providing an open ocean containment area. Electric fields have also been successfully experimented with to establish invisible barriers.

A lagoon-based energy and aquaculture system can provide multiple benefits for an island community. Many small atolls in the South Pacific have great potential for locating OTEC plants near large lagoons (e.g., 7-square-kilometer area) to generate power, fresh water, and provide nutrients for aquaculture in the enclosed lagoon. The lagoon system has great potential as a major food supply for millions of people. Directional drilling techniques can provide good access to offshore cold water, rich in nutrients.

Cold, deep water has been successfully used in aquaculture and biomass production. The natural phenomenon of high biological productivity in upwelling areas, while representing only 0.1% of the ocean's surface areas, produces about 40% of the world's fish. Pumping large amounts of cold water from depths down to 800 meters is analogous to upwelling. Based on the knowledge gained in pumping up deep, cold water for OTEC operations and secondary use for aquaculture as demonstrated at Keahole Point, Hawaii, an artificial upwelling system located offshore in Hawaii can result in enhancing the coastal fishery stocks. This concept was successfully demonstrated in Toyama Bay, Japan in July 1989. Islands such as Hawaii have little continental shelf and no shallow coastal waters to sustain a coastal fishery. Hence, most of the fish landings are deep ocean, pelagic fisheries. Yet the enormous ocean surrounding Hawaii has the potential for a vast coastal fisheries stock if a food chain were sustained and habitat were available. A concept that has great potential would be a field of floating artificial upwelling stations located in a coastal area where oceanographic characteristics would best retain upwelled nutrient-rich materials in the water columns. The artificial upwelling stations would basically have a spar-type configuration, with a long (400 to 800 m) cold water pipe and a pumping system powered by a bank of solar cells and/or a wave energy converter located on a buoyant, donut-shaped surface platform that also provides buoyancy for the pipe. The station would remain in position by simple, single-point mooring. Another possibility is to colocate artificial habitat structures to further enhance the area's fisheries productivity. The number of upwelling stations and artificial habitats could serve as the center of a self-contained, open ocean sea-ranching facility. The possibilities of attracting, retaining, and harvesting are innumerable. Also, the possibilities of sequestering CO_2 from the atmosphere through enhanced photosynthesis would be significant for a large network of artificial upwelling stations.

6. NATURAL HAZARDS

Earthquakes, tornadoes, and hurricanes are among the major natural hazards causing severe environmental damage and deaths, resulting in billions of dollars and losses. The general causes and effects are well known and documented, and technology for detection, assessment, and prediction is available.

The most recent technology advances for tornado detection and path prediction are based on the introduction of Doppler Radar. Besides providing customary weather services including marine forecasts, NOAA's National Weather Service began incorporating 115 next generation radars (NEXRAD) into a nationwide network of stations which is to be completed by 1997. These radar systems will be capable of detecting the dynamic velocity changes of wind-driven rains in the interior of a storm or tornado. Advanced signal processing and computer techniques are able to extract the velocity and direction of these winds and provide color-coded displays to illustrate severity and direction. Wind shear (adjacent winds moving in opposite directions) detected by Doppler Radar provides aircraft warnings of potential down drafts that can be extremely dangerous during landing patterns. In 1984, one of the most severe cyclonic storms in the southeast spawned 24 tornadoes that killed 67 people and injured over 650. In the future, advanced warning could result in saving many lives and moving out transportable property such as mobile homes, planes, other forms of transportation, and valuable items.

Over the last 40 years, about 25 major hurricanes (Category 3 & 4) were experienced in the U.S. with winds between 160 to 230 KM per hour, and storm surges between 3 to 6 meters; only one Category-5 hurricane was reported in 1969 with winds greater than 230 KM per hour and surges greater than 6 meters. Over this 40-year period, coastal regions have been developed considerably in the U.S., as well as in other Pacific Rim regions vulnerable to frequent hurricanes. A Category-5 hurricane would be devastating to a heavily developed coastal region. Hurricanes have caused considerable loss of lives and billions of dollars in damage from winds and especially storm surge. Storm surge is primarily generated by sustained hurricane-driven winds. NOAA has developed a storm surge numerical computer model technique called SLOSH (Sea, Lakes, and Overland Surge from Hurricanes) that provides early warnings to coastal communities and predicts the hurricane course, storm-surge levels, and extent of penetration over land. Computer models are available for 40 basins around the U.S. Atlantic Coast and Gulf of Mexico. An ordinary personal computer can run the model, using hurricane parameter inputs from the NOAA's National Weather Service such as position coordinates, storm size, and central pressure. A wind model is incorporated in the computer program. Computer-model inputs are provided every 6 hours, beginning 48 hours before landfall and ending 24 hours after landfall. Atlases for each basin show the maximum overland excursion of storm surge for different severity levels. This provides city planners with information to identify evacuation routes and locate emergency facilities. The computer programs provide emergency personnel with information on the course and severity of the impending hurricane to enable decisions regarding evacuation or other emergency measures.

7. GLOBAL ENVIRONMENTAL CHANGE

The global environment is constantly changing due to natural processes and periodic events, such as natural hazards and man-induced causes, resulting in global warming, ozone hole creation, marine pollution, and resource degradation and depletion. There are many international cooperative programs underway to measure and assess global environmental change. In response to global warming and ozone hole concerns, many developed countries have established policies, goals, and national programs.

In Japan, a global warming program was established to stabilize emissions of greenhouse gases at 1990 levels by 2000. The Japanese plan accepts the concept of global warming caused by burning of fossil fuels, and ultimately melting polar ice packs, raising sea levels, and submerging low-lying areas. The plan calls for reducing fuel oil consumption 58% to 51% by 2000 and to 45.3% by 2010. The plan proposes construction of nuclear plants, increased use of hydrogen fuel, more mass transportation, and more fuel-efficient cars.

The U.S. is waiting for the scientific community to make a decisive assessment before proposing any goals on global warming. However, in October 1990, Congress approved major additions to the Clean Air Act of 1970 aimed at significantly reducing acid rain, urban smog, airborne toxics, and ozone-depleting chemicals by 2000. Regarding acid rain, Congress proposed cutting 10 million tons per year of sulfur-dioxide emissions by 2000, a 50% reduction from 1980 levels. Regarding smog, it proposed cutting levels by 15% in the first 6 years and 3% per year thereafter until safe health standards can be attained. This requires reducing auto emissions of hydrocarbons and nitrogen oxides and using cleaner fuels. Regarding ozone depletion, recycling of CFCs (for cooling systems) is proposed beginning in 1992 and halting CFC production and halons by 2000 (the deadline imposed by an international treaty).

U.S. Global Change Research Program

In the U.S., the centerpiece of activity is the Global Change Research Program which involves substantial interagency cooperation, coordination, and integration of many individual and ongoing programs that also have components of international cooperation. This program's goal is to establish the scientific basis for national and international policymaking relating to natural and human-induced changes in the global Earth system. The related objectives are to: establish a comprehensive, long-term program of focused studies to improve understanding of the physical, geological, chemical, biological, and social processes that influence Earth system processes and trends on global and regional scales; and develop integrated predictive Earth system models. Each year, the Committee on Earth Sciences of the Federal

Coordinating Council for Science, Engineering, and Technology reviews the program to ensure that it continues to aggressively address its goal and objectives.

Examples of potential benefits of the program include the following:

- *Greenhouse Gases.* A better understanding of the processes, both natural and human-influenced, that govern the sources and fates of greenhouse gases will provide a basis for analyzing integrated control strategies and cost-benefit analyses.

- *Ozone Depletion.* Knowledge of the mechanisms controlling the stability of the stratospheric ozone layer to enable maintaining the "Montreal Protocol on Substances that Deplete the Ozone Layer."

- *Energy.* Facilitate the assessment of different energy technologies based on carbon dioxide emissions and atmospheric accumulation.

- *Agriculture/Ecosystems.* Knowledge of the linkages of crops, forests, and other ecosystems to environmental conditions will enhance the ability to make sound decisions regarding food security, forest management, and conservation of natural resources including crop selection, reforestation, and deforestation practices.

- *Water Policy.* Understanding interaction of the climate and hydrological cycles will help resolve issues involving water supply and demand, and will allow better planning for allocating water resources during extreme events.

- *Sea Level.* Understanding processes that control sea level will provide the predictive capability to guide policies regarding impacts on coastal communities and wetlands.

Funding for the total program was about $659 million in FY 90 and about $1 billion for FY 91. The major U.S. Federal participants in order of decreasing level of budget were NASA, NSF, DOE, NOAA, USDA, DOI, and EPA. In these seven agencies, over 100 projects focused on global change research, and some of the major projects included: Tropical Ocean-Global Atmosphere (TOGA); World Ocean Circulation Experiment (WOCE); Ocean Topography Experiment (TOPEX); Earth Observing System (EOS); and Global Ocean Flux Study (GOFS).

Tropical Ocean-Global Atmosphere (TOGA)

As a participant in the U.S. Global Change Program, NOAA is conducting this major climate project in the equatorial east central Pacific and, after 20 years, demonstrated the existence of interactions between tropical oceans and the global atmosphere. Such interactions are typified by the El Nino/Southern Oscillation (ENSO) phenomenon, which affects a large segment of the world's population living along the Pacific Rim. TOGA aims to establish an operational climate prediction capability and an observation network to support it. The program is concerned with: the response of the currents and thermal structure of the equatorial oceans to changing patterns of wind shears and other atmospheric forcing; and feedback of the tropical ocean dynamics on the global atmospheric circulation. The program intends to predict the state of the tropical ocean, including the distribution of sea level, thermocline depth, and sea surface temperature, out to 1 year or more in advance and to specify concurrent anomalies in tropical rainfall, jet stream locations, and storm tracks. Some success has been achieved in making forecasts of major swings in the ENSO cycle a season or more in advance, using statistical prediction techniques and simple dynamic models of the coupled atmosphere-ocean system. The U.S. is one of 18 participating nations involving NOAA, NSF, and NASA at a total U.S. level of about $20 million. About 75% of the funds are for data acquisition, including developing and installing an extensive observation network. This includes an array of about 16 moored Atlas buoys to measure wind speed and direction, air temperatures, and subsurface temperature to 500 meters and send multiplexed data via an ARGOS satellite transceiver. The TOGA observing network will continue to use data obtained via satellite from about 50 drifting buoys and from many ships of opportunity traversing the Pacific area. About 120 of the ships are equipped with NOAA's Ship Environmental Data Acquisition System (SEAS) to obtain XBT data, wave characteristics, surface temperatures, atmospheric pressure, and wind speed and direction, transmitted via satellite.

Global Ocean Observation Network

To address the U.S. Global Change Research Program objectives in providing the knowledge and understanding of the natural and human-induced changes in the global environment, a global ocean observation network is central to the program. Such a network is also central to providing data and information regarding marine pollution and marine environmental degradation.

In concept, a global network is used for: measuring and monitoring on a global synoptic scale; making observations and collecting data in time series (spanning micro and macro scale events); enabling researchers to make comparisons on a seasonal, annual, and decadal scale. The many programs identified in the U.S. Global Change Research Program, with a broad array of participating national and international organizations, are equipped in varying degrees to obtain observations and data relative to each program and/or as an element of a larger program. It is obvious that there is a wide diversity of: ocean platforms, measuring and observing systems, instrumentation, measuring and calibration techniques, data formats and modeling and analyses techniques. Frequently, there is little standardization (the degree is debatable) at interagency levels and often at intra-agency levels, let alone on an international scale. Data and observations derived from different sources must account for error deviations from many variables. This dilemma, which is manageable, should not deter from the principal thrust of getting qualified results from individual programs. Often time, concurrence on the general trend of the data is most significant and can be accompanied by estimates of possible deviations.

In developing a global ocean observation program, a systematic approach is necessary to keep things in proper perspective after the broad goals and objectives are stated. The first steps involve identifying the major problems and issues and placing some rank order on the criticality, timeliness, and importance. Scientific needs and requirements must be identified to address a broad scale of program elements ranging from obtaining a better understanding of the problem, to numerical modeling and long-term verification, and to routine monitoring and analyses. These needs and requirements establish a basis for engineering to provide for: design, development, system integration, deployment, operational, and calibration protocols, data formatting, collection and dissemination, and field support for logistics and maintenance. Before implementing scientific needs and requirements, an inventory should be made of existing platforms, instrumentation systems, and related supporting systems. Many of these systems are already available or can be modified for use.

NOAA has been working towards implementing a global ocean observation network by: incorporating present systems; adding to present systems; and expanding to incorporate new technology and systems. Some of the present NOAA systems include: the National Water Level Observation Network; Global Sea-Level Rise Network; TOGA ocean observing array; 9,000 Volunteer Observation Ships (VOS); program collecting meteorological and oceanographical data; National Data Buoy Network of 50 moored buoys and 40 coastal stations, and about 50 drifting buoys in the southern ocean for the TOGA Program; Geostationary Operational Environmental Satellite (GOES), NOAA polar-orbiting satellites, Navy GEOSAT; and access to data from international satellites and data observation networks.

By systematically collecting, analyzing, and storing data from observation networks from all international participating organizations, comparisons of like categories of information can be made on a seasonal, annual, and decadal basis to infer the scope and extent of global environmental change. International cooperation is essential and a central body is needed for planning, coordinating, and exchanging information.

Some examples of advanced technology that will also contribute to a global ocean observation network in the future include: acoustic tomography to characterize large expanses of ocean and infer temperature profiles useful in ocean-atmospheric heat transfer models; a fleet of AUVs programmed for long-range, long-duration ocean surveys with satellite interaction to control and transmit data; a network of automated bottom-mounted measurement stations with satellite interaction to monitor an entire estuary; and various underway, insitu, real-time monitoring systems to measure chemical and metal pollutants and water quality.

8. OCEAN SPACE UTILIZATION

Recent declarations of 200-mile EEZs have significantly expanded jurisdictions of ocean-bordering nations; for example, Japan by almost twelve, the United Kingdom by almost five, and Canada and the United States by almost two. The major beneficiaries in the near term will be the developed nations that have the technology and resources to exploit these vast new domains. About 85% of the U.S. EEZ and its resources are in the Pacific Basin, and the greatest rate of physical and economic development is occurring in Pacific Rim countries. Increased development to satisfy a burgeoning population's needs will mean extracting more resources from the EEZ, with the attendant problems of resource depletion, management of renewable resources, and the potential for continued environmental degradation by ignoring protective commitments, especially in the coastal ocean.

In the U.S., as well as in other ocean-bounded developed nations, population and industry are seeking closer locations to the coast, and the trend is increasing. For example, presently in the U.S., over half the population lives within 50 miles of the coast; by the year 2000, it could be as high as 75%. In Japan, because of the steepness of the mountains, only 30% of the land is habitable, most of which is along the coast where 70% of the people live. Even though inland space may be available, a strong desire and steadily increasing need exists to provide more coastal space for the coastal-oriented public seeking the ocean view, fresher air, marine recreation, and a better environment. As a result, development of ocean space in estuaries and coastal areas, including revitalization of ports, harbors, and coastal communities, is gaining momentum. Because of this demand for coastal ocean space, some coastal cities in Japan (Tokyo, Osaka, Kobe, and Yokohama) have introduced artificial island complexes providing seaward expansion. The most significant development is the artificial island for the Kansai International Airport, 5 km offshore from Osaka. Future concepts for seaward extensions, noted in the bibliography, include "Triportopolis - A Concept for an Ocean-Based Multimode Transportation and Communication Complex" and "Maritime Media Port Complex: Conceptual Design." Also, several proposals have been made for floating cities. In the U.S., major coastal developments include the ports of Los Angeles and Long Beach, and port of Baltimore. U.S. proposals have been made for large floating facilities such as ocean science stations, marine recreational parks, naval bases, and forward-area radar surveillance platforms.

Demands for coastal-related products and services, as well as scientific and technological advances, are dramatically changing human uses and perceptions of the coastal ocean. As a result, greater importance is being placed on more rational uses of ocean space with minimum conflict between the users. For these reasons, the concept of the ocean's multiple uses, particularly in coastal ocean regions, is becoming increasingly important. In this context, "coastal ocean space" is defined as the area from the high tide levels of the coastal region out to and including the continental shelf within the 200-mile EEZ of each coastal nation. A broad spectrum of activities in this ocean space include: fisheries development, extraction and management, energy and minerals extraction, marine transportation, port and harbor operations, coastal-dependent industrial activities, coastal living, and marine recreation.

Multi-use conflicts within the EEZ and coastal ocean are inevitable and sometimes desirable to obtain the greatest economic and social benefits. These conflicts, as well as related issues of inefficiency; delays in production; and losses due to non-use, are major concerns. These issues affect fulfillment of future needs, economic growth, and international competitiveness. Resolving multi-use conflicts requires a comprehensive, geographically organized information base on geological, physical, biological, chemical, and other characteristics of the coastal ocean. In addition, the data base should contain information on the location and extent of human activities in the coastal ocean region. This foundation, together with an understanding of specific multi-use conflicts, makes it possible to conduct initial, "strategic" assessments to determine the need for more site-specific data.

By understanding the users' varied needs and requirements, better decisions can be made about using the multiple resources of coastal ocean space. In the coming decades, the challenge will be to determine the most effective means of using ocean space for society's benefit. This challenge will involve the ability of nations to balance technological possibilities with social, economic, political, and environmental considerations.

The developed nations have the scientific and technological capabilities and means to protect the environment while extracting its resources. They need to set an example for the developing nations and third world nations to follow. Many of the lessons learned can be applied to coastal ocean development activities in developing nations, which can serve as models for studying and evaluating applications of lessons learned at early stages of coastal development. Cooperative workshops provide a useful mechanism for transferring technology to meet common goals. Some of the concepts discussed herein can assist developing nations and especially third world nations to improve their economic posture while protecting the environment. For example, island nations between 30°N and 30°S, can apply OTEC with aquaculture, artificial upwelling, open ocean ranching, and atoll fish farming, to provide them with basic needs of energy, food, and water. Energy can be used to establish or assist in developing their local products, including seafood products, that could also be exported to boost their economy and quality of life. For example, the U.S. can begin with the American Flag Pacific Islands (AFPI) and extend to other islands in the southwest Pacific and Caribbean.

9. INTERNATIONAL COOPERATION

The oceans provide a common medium that links all seafaring nations and profoundly affects their way of life. Whether for resource exploration and development, transportation, or recreation, our uses of the oceans inevitably have international implications. Increasingly, we turn to the oceans as sources of food, energy, minerals, chemicals, and space.

Seafaring nations share many common needs: developing their own Exclusive Economic Zones; addressing common problems in marine pollution and safe waste disposal; managing and developing ocean fisheries to provide maximum sustainable yields; assessing and extracting deep ocean minerals; and conducting global-scale scientific programs such as climate and global environmental change. Nations require the same technological advances to address these common needs in an efficient and effective manner. The advances needed cover a broad spectrum of technology topics and interdisciplinary solutions. Research and exploratory development activities leading to engineering development and feasibility demonstration of new systems are long, protracted and costly processes that are expensive for a nation to develop on its own. Therefore, a convincing rationale can be made for entering cooperative international ventures in sharing research and exploratory development phases of this technology, perhaps leaving product development and applications to a nation's own purposes.

Of course, many opportunities also exist for conducting international cooperation by pooling the use of each country's available technology and facilities and pursuing programs that transcend national boundaries such as: climate research, global environment change, and global sea-level rise. International cooperation on these programs were cited earlier.

Sharing and pooling technological resources means that each nation can obtain a greater return on investment by leveraging through cooperation. Furtherfore, international cooperation promotes better cross-pollination of ideas and encourages different perspectives. In all cooperative ventures, project support and participation must be shared in an equitable manner.

Nation-to-nation agreements are necessary to coordinate cooperative ventures and equitable technology exchange. Responsible leaders of all seafaring nations should insist upon energetic and full participation in international activities associated with the peaceful and responsible utilization and protection of the oceans and their resources.

The U.S. is involved in hundreds of cooperative international projects. In the oceans, some of the major bi-lateral agreements and programs are listed in Table 1.

These cooperative agreements have spawned many small scale and several large scale projects over the years. An example of a large scale project was the U.S. —France Project FAMOUS (French-American Mid-Ocean Undersea Studies) in the mid-70s and now being repeated again, 15 years later, as project FARA (French-American Ridge Atlantic). Bi-lateral programs are especially valuable for equitable exchange of research results, and science and technology advances.

Many international workshops on ocean engineering research were sponsored by the National Science Foundation (NSF) (see Table 2). Some of these were initiated as a result of the existing cooperative agreements.

Table 1.— Bi-Lateral Agreements and Programs

Country/Year Started	Ocean Technology Related Topics
U.S.—Japan Science and Technology Agreement (1988)	. Biotechnology . Automation . Global Geoscience and Environment . Advanced Materials
U.S.—Japan Cooperative Program in Natural Resources (1964)	. Marine Facilities . Diving Physiology and Technology . Marine Electronics & Communications . Sea Bottom Surveys . Marine Geology . Marine Mining . Aquaculture
U.S.—France Cooperation in Oceanography (1971)	. Marine Technology . Man-in-the-Sea . Marine Data Systems . Climate and the Oceans . Control of Marine Pollution . Ship-time Interchange . Aquaculture
U.S.—China Cooperation in Marine and Fisheries Science and Technology (1979)	. Marine Technology . Marine Data Exchange . Marine Pollution . Environmental Monitoring . Climate and the Oceans

The objectives of the NSF workshops were to: exchange information on technology advances; idenfity research needs for future projects; explore the possibilities of cooperative international proposals to share in conducting engineering research toward a common goal; and integrate the resulting research to meet specific objectives of mutual benefit.

10. CONCLUSIONS

The major problems of global environmental degradation are: global warming, ozone hole creation, marine pollution, acid rain, resource degradation and depletion, and natural hazards. These can all be grouped under global environmental change. Some of the development activities of the past and present (e.g., fossil fuel combustion systems; operations of refineries, industrial plants, power plants, and incinerators; operation of marine transportation systems; coastal ocean discharge and ocean dumping practices; and exploitation of resources) have contributed to environmental degradation in varying degrees. The past is history, with many lessons learned and an understanding that future development activities must be undertaken with regard for the environment and the realization that a healthy economy can only survive with a healthy ecology.

With this in mind, some of the major ocean development activities or projects that should be pursued follow.

Monitoring the Environment

- Expand global ocean observation networks to monitor global change.
- Promote international cooperation and information exchange.
- Provide large scale climate monitoring, modeling, and prediction capability.
- Provide standardization and calibration of measurement systems.
- Provide rapid, real-time in-situ environmental measurement and monitoring systems.
- Develop AUV-satellite systems for environmental monitoring of large coastal estuaries.
- Develop acoustic tomography to characterize large expanses of ocean.
- Expand: data collection and analysis; electronic storage and access of data using GIS techniques; and strategic assessment capabilities.
- Strengthen hazardous materials response capabilities.

Table 2.— NSF Workshops on Ocean Engineering Research

Countries and Period	Workshop Topics
U.S.— France (1987-91)	. AUV & Underwater Robotics . Marine Materials . Marine Biotechnology
U.S.— Japan (1989-90)	. Ocean Space Utilization . AUV & Underwater Robotics . Seafloor Survey . Artificial Upwelling
U.S.— Norway (1989-91)	. AUV & Underwater Robotics . Aquaculture
U.S.— Argentina (1991-92)	. Ocean Space Utilization
U.S.— Multi-National (1991)	. Open Ocean Mariculture

Halt Degradation — Seek Improvements

- Promote conservation of energy practices affecting design codes for buildings and transportation systems to reduce energy needs.
- Provide nonpolluting, energy-efficient marine transportation systems.
- Improve CO_2 scrubbing techniques.
- Convert combustion systems to cleaner fuels.
- Develop cost-effective solar and solar-derived energy systems such as solar cells and various ocean energy systems.
- Develop small scale (under 5 MW) commercial OTEC plants for the vast island market to provide electric power, nutrients for aquaculture, and fresh water.
- Develop larger scale OTEC plants as technology matures in the island market.
- Develop wave energy conversion systems in areas of high wave energy density to extract electrical power and provide breakwaters for calmer coastal waters.
- Install tidal energy systems where criteria are met.
- Convert ocean energy and hydroelectric power to hydrogen for energy storage and cleaner fuel consumption.
- Find alternatives to CFCs products.
- Improve automated recycling systems as a cost-effective alternative to disposal.
- Develop safe and efficient incineration systems for present land-based systems and future potential for offshore systems.
- Explore safe use of EEZ for disposal of dredged material and some forms of municipal waste.
- Study the potential of sub-seabed disposal of low-level radioactive waste in geologically stable deep ocean areas.
- Improve navigation and vessel traffic control systems to reduce possibilities of collisions and groundings.
- Complete development of double hull tankers for all international tanker fleets.

Restoring the Environment

- Create man-made wetlands to replace losses of wetlands.
- Consider the economic value of environmental assets to society in evaluating real estate values of wetlands.
- Enhance fisheries stocks by open ocean ranching, artificial upwelling, and artificial habitats.
- Develop lagoon-based energy and aquaculture systems on tropical atolls.
- Improve natural hazard/warning networks to predict tornadoes, severe storms, and hurricanes.

Ocean Space Utilization

- Increase capabilities for assessment and development of resources of the EEZ to satisfy growing population needs.
- Develop a comprehensive data base of everything in and about the EEZ, especially an assessment of its resources, to enable safe extraction and conservation.
- Plan and implement wise development and multiple usage of coastal space including revitalizing of ports, harbors, and coastal communities.
- Consider expansion of overcrowded coastal communities and facilities by seaward extension using artificial islands and floating facilities.
- Assist developing nations and third world nations by providing the scientific and technological means for extracting resources while protecting their environment.

In conclusion, ocean science and technology will play a very important role in restoring the global environment and safely developing the oceans and their vast resources to satisfy growing population demands, while ensuring conservation and resource renewa-bility for future generations. Above all, the main goal must aim to improve or at the very least maintain an acceptable standard of living for all mankind.

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12. DISCLAIMER

The concepts and ideas presented in this paper are the views shared by the author and do not necessarily represent the views of any organization in which he is affiliated.

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