U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

NOAA Strategic Plan

A Vision for 2005

May 1996

1995-2005 NOAA Strategic Plan

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U.S. DEPARTMENT OF COMMERCE
Michael Kantor, Secretary

National Oceanic and Atmospheric Administration
D. James Baker, Under Secretary for Oceans and Atmosphere and Administrator

May 1996

DEDICATION

The men and women of NOAA dedicate this strategic plan to the late Ronald H. Brown, the 30th Secretary of Commerce, and to our other colleagues who gave their lives in the service of the Nation. Their vision for America and commitment to public service will continue to inspire and influence our daily work.

Foreword from the Administrator

This 1995 edition of the NOAA Strategic Plan continues the significant effort to define NOAA in the 21st century begun with the 1993 Strategic Plan. It sets forth NOAA's vision for the year 2005, a world in which societal and economic decisions are coupled strongly with a comprehensive understanding of the environment. The Plan is the result of a critical examination of NOAA's current statutory and program responsibilities viewed in the light of the significant environmental and fiscal issues facing our Nation.

The Plan unfolds into two fundamental missions. The Environmental Assessment and Prediction mission and the Environmental Stewardship mission each describe in practical terms the challenge before us, the objective of our efforts, the benefits to the Nation, and NOAA's strategy to achieve the vision. These are followed by a discussion of NOAA's unique national capabilities and supporting infrastructure which are critical to the execution of NOAA's goal-based strategy. The Introduction, NOAA's Vision for 2005, provides a summary of the Strategic Plan. A September, 1995 companion document entitled, Strategic Plan, A Vision for 2005, Executive Summary, is available upon request.

The Plan defines our activities and forms the basis for long-term management and resource decisions. It focuses on the results the agency wants to achieve, and facilitates cross-organizational contributions toward meeting goals. Although the Plan does not prioritize among the goals, it does drive NOAA's budget and operating plan process, and as such is a critical document for management decisions.

I believe that NOAA's investment in strategic planning is an institutional necessity. The drive to balance the federal budget should be a clarion call to all government agencies to assess what they are doing, to understand why they are doing it, and to build support for their activities for the future. Agencies will be called upon to do more with less and to demonstrate the direct contributions they can make to the well-being of all Americans.

With this in mind, NOAA must balance the reality of fiscal constraints with the goals set forth in this Plan. The Strategic Plan, as it guides the development of implementation plans, budgets and annual operating plans, will help us set the right priorities to ensure that the important work of NOAA is done most effectively.

I am proud to present this Plan, and would like to congratulate the women and men of NOAA, and our partners and customers, who have made this a working reality. I encourage your comments on the Plan and your participation in NOAA's exciting future.

D. James Baker

Preface

The NOAA Strategic Plan has been developed by teams comprised of representatives from throughout the agency. It reaffirms and builds upon previous efforts which produced our seven strategic goals. This update to the Plan incorporates extensive input from our employees at all levels in the organization, and from our customers and constituents. There are too many people to recognize individually but special recognition is due two groups: the NOAA Team Leaders, whose unfailing efforts to articulate a comprehensive and clear understanding of NOAA's vision for the future have contributed immensely to this process; and the Office of Policy and Strategic Planning staff who are responsible for the oversight and conduct of the strategic planning process.

Comments on the NOAA Strategic Plan are invited. We would like to hear from you regarding the vision for NOAA's future and how we can get there. With your help, this strategic planning process will continue to refine NOAA's goals and reflect the interests of our constituents and those whom we serve with pride -- the American public.

Your comments on the NOAA Strategic Plan should be directed to:

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INTRODUCTION

VISION

For the year 2005, NOAA envisions a world in which societal and economic decisions are coupled strongly with a comprehensive understanding of the environment.

The National Oceanic and Atmospheric Administration's mission is to describe and predict changes in the Earth's environment, and conserve and manage wisely the Nation's coastal and marine resources to ensure sustainable economic opportunities. Through strategic planning, NOAA evaluates how best to accomplish this mission. The strategic plan provides a framework for articulating program goals and builds to these goals through consensus. The planning process promotes synergy, innovation and efficiency. It represents a better way of doing business.

NOAA envisions a 21st century in which environmental stewardship, assessment, and prediction serve as keystones to enhancing economic prosperity and quality of life, better protecting lives and property, and strengthening the U.S. balance of trade. This vision depends on actions now that:

- Create and disseminate reliable assessments and predictions of weather, climate, space environment, ocean and living marine resources, nautical, aeronautical and geodetic phenomena and systems.
- Implement integrated approaches to environmental management and ocean and coastal resources development for economic and social health.
- Ensure continuous operational observing capabilities -- from satellites to ships to radars.
- Build and use new information networks.
- Develop public-private and international partnerships for the expansion and transfer of environmental knowledge and technologies.
- Invest in scientific research and the development of new technologies to improve current operations and prepare for the future.
- Improve NOAA's abilities to serve its customers and forge stronger ties with its partners and stakeholders.

THE CHALLENGE TO NOAA

NOAA's historical role has been to predict environmental changes, protect life and property, provide decision makers with reliable scientific information, and foster global environmental stewardship. Our goals and programs today reflect a commitment to these basic responsibilities in the service of our customers and the Nation.

Over the past 25 years, technology and scientific insights have allowed the United States to make important strides in understanding and predicting the behavior of natural systems, in managing resources more effectively, and in improving environmental quality. NOAA's sciences and services have been fundamental to these accomplishments. Although we are better prepared to address the environmental challenges of the 21st century, we must recognize the unremitting and increasingly complex nature of these challenges. For instance:

- Our dynamic natural surroundings affect life, property and human actions on a daily basis. Short-term environmental events, particularly severe weather, can be socially and economically devastating. The ability to prepare for emergencies and to extend planning horizons for general activities depends on the quality and timeliness of our observations, assessments, and information delivery. The challenge is to improve our understanding of the environment so that we can minimize its effects on human activities. Expanding population and economic development are driving the need for a comprehensive system of environmental observations, assessments, predictions and information delivery.

- Many marine species are under stress from a combination of habitat degradation, overexploitation and competing economic concerns. Of the U.S. fishery resources for which population status is known, 36% are overutilized and 44% are fully utilized[1]. Some marine mammals, turtles and fish currently are threatened with extinction. These endangered species are critical to the maintenance of biodiversity and the stability of natural ecosystems. The challenge is to return our living marine resources to healthy population levels to enhance opportunities for future generations.

- Dramatic seasonal to interannual climate variations have been linked to the El Niño-Southern Oscillation (ENSO) phenomenon in the tropical Pacific. ENSO-related effects include severe drought, ocean warming, and regional flooding. NOAA has begun issuing seasonal outlooks of climate variability based on ENSO research. However, the ability to improve the accuracy and reliability of ENSO outlooks is hampered by the extent of observations and the need for enhanced process understanding and modeling. On the decadal to centennial time scale, human-induced and natural changes in the

[1] *Our Living Oceans: Report on the Status of U.S. Living Marine Resources, 1995.* NOAA Technical Memorandum NMFS-F/SPO-19 (U.S. DoC, NOAA, National Marine Fisheries Service, February 1996).

global environment may alter the capacity of the Earth to sustain life. Atmospheric pollution and the thinning of the ozone layer are human-induced changes affecting societies and governments. The challenge is to forecast seasonal through centennial changes with predictions of sufficient scientific credibility to support action.

- U.S. coastal counties are growing in population at a faster rate than inland counties. Coastal areas provide essential habitats for over 75% of U.S. commercial fisheries landings[2], and serve as the foundation for billions of dollars in economic activity, including maritime commerce. In fact, 98% of our international trade by bulk leaves our shores through coastal ports. Rapid growth and development in coastal areas also has contributed to resource degradation and declines in environmental quality and economic productivity. For instance, portions of the Nation's shellfish beds have been closed repeatedly for some or all of recent harvest seasons due to water quality concerns. In 1992, beaches were closed or advisories issued against swimming on almost 3,000 occasions because of pollution[3]. Utilization of positioning technologies and information has not kept pace with an expanding volume of maritime traffic, leading to reduced efficiency and increased risk of accidents. The challenge is to enable sustainable development in the coastal zone by maintaining healthy ecosystems, balancing resource use and protection, and providing the information and technologies needed to support economic growth.

By addressing environmental challenges, NOAA works as an integral part of the Department of Commerce to further the Nation's capabilities for sustainable development. As stated by former Secretary Ronald Brown, "Economic growth can--and must--go hand in hand with environmental stewardship. The development of policies that strengthen the links between environmental stewardship and economic growth is central to the Administration's agenda and is a core concern of the Department of Commerce."[4] Embracing this linkage between economic and environmental goals has been a guiding principle for NOAA. *Such a bond is critical to preserve national and economic security in a constantly changing world.* NOAA's planning and mission evaluation efforts help define the goals and programs necessary to address these challenges.

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[2] *Habitat Protection Activity Report 1991-1993* (U.S. DoC, NOAA, National Marine Fisheries Service, August 1994).

[3] Weiant, P., *Testing the Waters IV: The Unsolved Problem of U.S. Beach Pollution* (Natural Resources Defense Council, New York, August 1994).

[4] *To Ensure the Nation's Future: Sustainable Development and the U.S. Department of Commerce* (U.S. DoC, December 1994).

ACHIEVING NOAA'S VISION FOR 2005

NOAA's Strategic Plan for 1995-2005 describes the goals and objectives that have been established to fulfill its vision. The strategy consists of seven inter-related goals. Each goal is a coherent unit, but there also are important cross-cutting relationships which enable the implementation and advancement of national, Department of Commerce, and NOAA objectives. The goals are grouped within the two primary missions of *Environmental Assessment and Prediction* and *Environmental Stewardship.*

Environmental Assessment and Prediction Mission:

- Advance Short-Term Warning and Forecast Services
- Implement Seasonal to Interannual Climate Forecasts
- Predict and Assess Decadal to Centennial Change
- Promote Safe Navigation

Environmental Stewardship Mission:

- Build Sustainable Fisheries
- Recover Protected Species
- Sustain Healthy Coasts

The execution of NOAA's goal-based strategy depends strongly on a stable infrastructure and administrative and human resources, as well as on the underlying capabilities of the agency as a national resource for research, observing systems, and environmental data and information services.

Each mission, the seven strategic goals, and NOAA's national capabilities are summarized in the following pages.

Environmental Assessment and Prediction Mission. *For 2005, NOAA envisions integrated environmental observation, assessment, and forecast services that enhance public safety and the Nation's economic and environmental security.*

- **Advance Short-Term Warning and Forecast Services**

  Vision. NOAA's vision for 2005 is to provide significantly improved short-term warning and forecast products and services that enhance public safety and the economic productivity of the Nation. NOAA will enhance its ability to observe, understand, and model the environment, and effectively disseminate products and services to users.

  Challenge. Our environment has profound effects on human welfare and economic well being. Each year, hundreds of lives and billions of dollars are lost due to severe storms,

floods and other natural events that could be predicted minutes to months in advance. NOAA's current ability to predict short-term change is restricted by observations that are incomplete in time and space. This limits the ability to improve basic understanding, and predictive modeling of weather and other natural phenomena. Although we can do nothing to prevent natural disturbances, we must do everything possible to minimize their human impact. NOAA must improve its observing systems, develop a better understanding of natural processes, and enhance predictive models and dissemination systems.

Implementation Strategy. The objectives of this goal are to:

- Complete the modernization and restructuring of the National Weather Service (NWS) to ensure the continuation of effective services.

- Maintain continuous operational satellite coverage critical for warnings and forecasts.

- Strengthen observing and prediction systems through scientific, technological and programmatic advances, and international cooperation. This objective will be achieved in cooperation with the U.S. Weather Research Program (USWRP) by incorporating the scientific and technologic advances from the USWRP into service improvements.

- Improve customer service to the public, emergency managers, the media and private forecast planners through effective communication and utilization of NOAA's products.

Benefits. Increasing our understanding of the environment through research and investing in new technologies will provide more accurate and timely warnings and forecasts required by the Nation. Improved forecasts will support management of water resources, and help avoid flood damage. Extended forecasts of solar and geomagnetic disturbances will increase efficiencies for space operations, and power generation and satellite communications networks. Advanced modeling techniques and more complete observations will reduce uncertainties in hurricane track prediction, saving millions of dollars through evacuation costs avoided. Accurate outlooks of future conditions will provide better information for planning weather sensitive activities over land and ocean.

Improvements associated with the NWS modernization will pay for themselves. A National Institute of Standards and Technology cost-benefit analysis for the modernized NWS estimates that economic benefits to the Nation will be about eight times greater than the costs involved. Once modernization is complete, the Nation will realize annual benefits beginning at $7 billion[5].

[5] *Benefits/Cost Study for the Modernization and Associated Restructuring of the National Weather Service* (U.S. DoC, National Institute of Standards and Technology, 1991).

- **Implement Seasonal to Interannual Climate Forecasts**

Vision. NOAA, working together with academic and multinational partners, will provide one-year lead-time forecasts of known skill of global climate variability, especially El-Niño and the consequent precipitation and surface temperature distributions. These forecasts will increase society's ability to mitigate economic losses and social disruption.

Challenge. The largest interannual climate variability that has a degree of predictability is caused by the El Niño-Southern Oscillation (ENSO) phenomenon in the Pacific Ocean. Temperature and precipitation patterns, changes in ocean circulation, and changes in storm frequency caused by ENSO have global effects on economies and planning. Based on the application of ENSO-related research, NOAA has begun issuing monthly and seasonal probability outlooks for temperature and rainfall for up to a year in advance. The immediate challenge is to introduce an operational program for the systematic production and application of regionally-tailored climate forecasts. Planned actions represent an end-to-end integrated approach to establishing such a system, including the multinational infrastructure needed to generate and transfer useful climate information and forecasts.

Implementation Strategy. The objectives of this goal are to:

o Deliver useful seasonal to interannual climate forecasts for the U.S. and collaborate in a multinational effort to generate and use similar forecasts.

o Enhance global observing and data systems required to provide data for the initialization and validation of model predictions of seasonal to interannual climate variations.

o Invest in process and modeling research that leads to improved predictability of temperature and rainfall distributions.

o Assess the impacts of climate variability on human activity and economic potential, and improve public education so that climate forecasts are understood and acted upon.

Benefits. We can now predict El Niño events to a level of skill and with enough lead time that hundreds of millions of dollars a year could be saved both in the U.S. economy and abroad. ENSO forecasts will improve fisheries management, as warm ENSO events have been associated with reduced marine catches from Peru to Alaska. Global forecasts of climate variability will enhance agricultural, water resources, and other economic and social response planning. An estimate of the averaged value of an ENSO forecast approaches $1 billion annually across all economic sectors[6]. These forecasts will be a

[6] *Toward a Global Ocean Observing System: The Case for GOOS*, IOC/INF-915 (Intergovernmental Oceanographic Commission, UNESCO, Paris, France, 1993).

major contribution to U.S. commitments to the United Nations Conference on Environment and Development (UNCED).

- **Predict and Assess Decadal to Centennial Change**

Vision. NOAA will provide science-based options for decisions regarding decadal to centennial changes in the global environment, specifically for: climate change and greenhouse warming; ozone layer depletion; and air quality improvement.

Challenge. Our planet is naturally a place of change, often with severe impacts on humans. Human activities now are inducing additional changes, with potential impacts of comparable magnitude. Human-induced changes already are evident, including atmospheric pollution and thinning of the stratospheric ozone layer. Greenhouse gases being added to the atmosphere will reside there for decades to centuries and are predicted to increase average global surface temperatures. These changes create critical prediction and assessment needs for the world community. Global models providing predictions must be strengthened through implementing global observing systems. The challenge is to understand and foresee the natural and human-induced variations of the approaching few decades in order to make sound economic and social decisions.

Implementation Strategy. The objectives of this goal are to:

o Characterize the agents and processes that force decadal to centennial climate change.

o Examine the role of the ocean as a reservoir of both heat and carbon dioxide to address a major source of uncertainty in climate models.

o Ensure a long-term climate record by enhancing domestic and international weather networks, observing procedures, and information management systems.

o Guide the rehabilitation of the ozone layer by providing the scientific basis for policy choices associated with ozone-depleting compounds.

o Provide the scientific basis for better air quality by improving the understanding of high surface ozone episodes in rural areas and by establishing a monitoring network to detect cleaner air quality.

o Develop models for the prediction of long-term climate change, carry out scientific assessments, and provide human impacts information.

Benefits. Anticipatory research on climate change supports sustainable development by enabling society to make sound decisions to mitigate and adapt to climate change, to assess the utility of our large investment to reduce greenhouse gas emissions, and to

improve regional air quality. Performing research, presenting results in up to date assessments, and describing the implications in policy-relevant terms to government and industrial leaders are cornerstones of environmental stewardship. The benefits can be enormous. The value of reducing climate-related uncertainty in the implementation of policies on stabilizing anthropogenic greenhouse gas emissions is estimated to be $100 billion for the U.S. alone between now and the year 2020[7]. Assisting industry to choose the most "ozone-layer friendly" substitutes for chlorofluorocarbons will promote protection of the stratospheric ozone layer while continuing economic development. Scientific findings will assist Clean Air Act decisions to reduce surface ozone, with benefits to human health and agriculture.

- **Promote Safe Navigation**

Vision. By 2005, merchant ships, fishing vessels and recreational boats will safely ply our coastal waters, electronically guided by space-based navigation and advanced information technologies. NOAA will revolutionize U.S. marine and air navigation, mapping and surveying and assist commercial shipping in moving increased cargoes safely and efficiently. NOAA will provide a precise satellite derived reference system as the basis for the Nation's nautical data and geographical positioning needs.

Challenge. Ships have doubled in length, width and draft in the last fifty years and seagoing commerce has tripled, leading to increased risk in the Nation's ports. Greater dependence on foreign oil has increased the potential for disaster due to spills. From 1980 to 1988, tankers in the U.S. were involved in 468 groundings, 371 collisions, 97 rammings, 55 fires and explosions, and 95 deaths[8]. Navigation tools must be modernized. For instance, 60% of NOAA's nautical charting data were obtained before 1940 with obsolete methods. Obstructions are reported faster than they can be surveyed and entered on charts. Two-thirds of the data used for tidal predictions are more than forty years old and NOAA has withdrawn the tidal current charts for New York and San Francisco due to inaccuracies. The existing coordinate reference system must be renovated to provide the higher accuracy and accessibility available from the Global Positioning System (GPS). Nautical charting, coastal zone geographic information systems, high precision agriculture, intelligent highway vehicle systems, and other uses of the Nation's annual investment of $7 billion in spatial data depend upon convenient access to a GPS-based reference system.

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[7] Manne, A. and R. Richels, *Buying Greenhouse Gas Insurance: The Economic Costs of Carbon Dioxide Emission Limits*, Chapter 4, Decision Making Under Uncertainty (MIT Press, 1992).

[8] *No Safe Harbor; Tanker Safety in America's Ports* (Natural Resources Defense Council, New York, 1990).

Implementation Strategy. The objectives of this goal are to:

- o Build, maintain and deliver a digital nautical charting database to underpin new electronic navigational systems which integrate satellite positioning, tidal heights and currents, radars and sonars, and navigational aids.

- o Update nautical surveys of the Nation's coastlines and coastal ocean areas using full-bottom coverage technologies.

- o Install measurement and communication systems to provide mariners with real-time observations and forecasts of water levels, tides and currents, and weather conditions in major ports.

- o Transform the obsolete geodetic reference frame into a GPS-based system of monumented marks and continuously-operating reference stations to support the digital revolution in mapping, charting and surveying.

- o Provide modern aeronautical navigation information.

Benefits. New electronic technologies promise to reduce maritime transportation risks and heighten the competitiveness of the U.S. shipping industry. A modernized GPS-based geodetic reference network using federal standards will maximize the economic benefit of positioning investments and provide a foundation for the success of U.S. firms abroad. These technologies also will support the needs of coastal zone planners, regulatory officials and researchers as they work to ensure the safe, sustainable and efficient development of our coastal and ocean resources.

Environmental Stewardship Mission. *For 2005, NOAA envisions U.S. ocean and coastal areas with healthy ecosystems and the wise human use and development of ocean, coastal and living marine resources.*

- **Build Sustainable Fisheries**

Vision. NOAA's vision for the next decade is to increase greatly the Nation's wealth and quality of life through sustainable fisheries that support fishing industry jobs, safe and wholesome seafood and recreational opportunities.

Challenge. Billions of dollars in economic growth, thousands of jobs and countless recreational fishing opportunities are being wasted as a result of overfishing and overcapitalization in commercial and recreational fisheries. While many fisheries are well managed and producing positive benefits, others are severely depleted, and must be restored to realize their long-term potential. For example, the historically important New England groundfish fishery closed in 1994 due to the collapse of stocks. Transboundary

resources can be especially vulnerable as they require international cooperation to achieve effective conservation and management. U.S. fisheries are troubled by bycatch, including juvenile and protected marine species, and by controversial allocation decisions among elements of fishing industries. Uncertainty in scientific information makes management decisions difficult.

Implementation Strategy. The objectives of this goal are to:

- o Assess the status of fishery resources, through stock assessments and population dynamics research, to improve the scientific basis for policy decisions.
- o Advance fishery predictions through research and applications.
- o Manage for economic growth and sustainable fisheries by working with Fishery Management Councils, foreign nations and others to develop plans for reducing excessive fishing and capital investment.
- o Ensure adequate compliance with fishery regulations.
- o Provide research and services for fishery-dependent industries to maximize the potential benefits from the Nation's marine resources.

Benefits. Rebuilding and maintaining fisheries will promote the economic and biological sustainability of U.S. fishing resources, and assist the commercial fishing industry in becoming more competitive internationally. NOAA estimates that restoring fisheries may add as much as $2.9 billion in potential net value to the U.S. economy as overfished stocks recover and over-harvesting is reduced. A potential $25 billion total impact on the national economy (direct, indirect and induced) will develop thousands of new jobs[9]. Along with economic gains, this activity will enhance recreational opportunities, reduce our seafood trade deficit, improve the federal oversight and management of fisheries, and save lives by eliminating the dangerous and wasteful race for the fish.

- **Recover Protected Species**

Vision. NOAA's vision is to conserve marine species and to recover those in danger of extinction. By 2005, NOAA will be on the road to recovering every marine species at risk and maintaining healthy marine ecosystems upon which they depend.

Challenge. Marine resources contribute billions of dollars to the Nation's economy. However, many commercial and recreational activities contribute to stress on marine

[9] Sissenwine, M. and S. Swartz, *Analysis of the Potential Economic Benefits from U.S. Fisheries*, Internal Report of the Office of the Senior Scientist (U.S. DoC, NOAA, National Marine Fisheries Service, 1992).

species. Many populations of marine organisms are depleted or declining due to human activity in marine ecosystems or to unknown causes. For example, west coast salmon populations are at risk due to a combination of factors including habitat loss and commercial overexploitation. Despite protective measures, fishing-related mortality continues to threaten marine turtles in U.S. waters. Several seal and sea lion populations in Alaska are declining rapidly, and the causes are uncertain. While many recovery plans have been developed, none have been implemented fully and plans still are needed for many species. The desired outcome is to recover protected species in danger of extinction in a manner compatible with the sustainable use of marine resources.

Implementation Strategy. The objectives of this goal are to:

- o Assess the status of, and impacts to, protected species. Information is needed to better focus management actions, limit the scope of restrictions, and promote the recovery of all protected species.

- o Develop and implement conservation and recovery plans for depleted marine mammals and endangered and threatened species. This will be done in part through developing new partnerships with state and private sectors. Technologies and measures will be developed to reduce or avoid detrimental interactions between marine species and human activities.

Benefits. Through conservation of the Nation's living marine resources, NOAA will enhance economic and cultural opportunities for future generations. The existence of the Marine Mammal Protection Act, the Endangered Species Act and other legislation provides a clear indication of public support for strong efforts to conserve living marine resources. This effort will enable the preservation of marine biodiversity by balancing the utilization of natural resources with the management of protected species. Recovering species, and avoiding the further decline of others, will contribute to the overall health and understanding of marine ecosystems. Improved science will lead to better long-term management and conservation strategies.

- **Sustain Healthy Coasts**

Vision. By 2005, the Nation's coasts will have more productive and diverse habitats for fish and wildlife, and cleaner coastal waters for recreation and the production of seafood. Coastal communities will have thriving, sustainable economies based on well-planned development and healthy coastal ecosystems.

Challenge. Over half (54%) of the U.S. population lives on the 10% of land area defined as coastal[10]. Between one-third and one-half of U.S. jobs are located in coastal areas. About one-third of the nation's Gross National Product is produced there through fishing, transportation, recreation, and other industries dependent on healthy coastal ecosystems for growth and development. Coastal areas, for example, provide essential habitats for the majority of commercially valuable marine species. But habitat loss, pollution and overfishing have reduced populations of coastal fish and other species to historically low levels of abundance and diversity. Rapid population growth and increasing demands for recreation and economic development in many coastal areas have degraded natural resources and led to declines in both environmental integrity and general productivity. The closure of beaches and harvesting areas is evidence that such conditions threaten businesses and human health. Maintaining the health and biodiversity of coastal ecosystems is essential to the sustainable development of coastal resources and economies, and to the future welfare of the Nation.

Implementation Strategy. The objectives of this goal are to:

- Protect, conserve and restore coastal habitats and their biodiversity.

- Promote clean coastal waters to sustain living marine resources and ensure safe recreation, healthy seafood and economic vitality.

- Foster well-planned and revitalized coastal communities that sustain coastal economies, are compatible with the natural environment, minimize the risks from natural hazards, and provide access to coastal resources for the public's use and enjoyment.

Benefits. The fabric of our coasts is as fragile as it is beautiful. Improved understanding of the way coastal ecosystems function, coupled with an ability to predict responses of ecosystems to human activities, are keys to an approach that ensures that the Nation's coastal ecosystems are managed for long-term benefit. This goal addresses the practical needs and concerns of resource managers, as well as strengthening the watershed and regional management frameworks provided by state Coastal Zone Management programs. An integrated program of monitoring, process research, modeling, assessments and information dissemination will provide the scientific basis for measures designed to prevent harm to ecosystems while allowing sustainable development.

[10] Culliton, T., et al., *50 Years of Population Change Along the Nation's Coasts, 1960-2010*, Coastal Trends Series, Report 2 (U.S. DoC, NOAA, National Ocean Service, 1990).

National Capabilities and Supporting Infrastructure. *The successful execution of NOAA's missions and goals depends on our capabilities as a national resource for research, observing systems, and environmental data and information services; and on our supporting infrastructure. NOAA must continue to invest in these capabilities, which serve as the foundation of our programs.* NOAA's assets include:

- **Research**

  NOAA conducts research to support its management and service goals and to provide the basic knowledge that underpins decisions and analyses. A strong research capability is necessary to: ensure continuity and improvements to existing services; provide the knowledge and technical base to integrate scientific data in support of applications and management; and to enable the agency to meet emerging national needs and anticipate future needs and opportunities.

  NOAA's research activities have, for decades, enabled improvements to operational capabilities. NOAA laboratories and program efforts also support research on natural processes, populations, and environments. The challenge of prediction, a primary NOAA business, requires the integration of observations, modeling, and process knowledge. These capabilities enable others to make credible and cost-effective decisions regarding a host of environmental issues both of national and global scope.

  The long-term view and direct management responsibilities impel NOAA to continue to improve its connections between applied research and operations, to incorporate new technology, and to adopt a systems perspective in integrating traditional disciplines in the study and management of ecosystems.

- **Observing Systems**

  The most fundamental NOAA activity is the description of the physical, chemical, and biological properties of the Earth and its environments. A sound observational and monitoring capability is vital to the success of NOAA and the Nation. NOAA's vision for the 21st century is of a modern, integrated and comprehensive system of observing platforms and networks to provide the quality data and information needed to support NOAA and national goals. For example, NOAA's investment in weather service modernization is resulting in dramatic improvements in capabilities and services.

  NOAA obtains observations in locations ranging from outer space to the ocean bottom, and places a high priority on the continuity of observations. Observing *platforms* include satellites, aircraft, ships, buoys, submersibles and platforms of opportunity. During 1994, NOAA, the Department of Defense and the National Aeronautics and Space Administration agreed to combine resources and expertise to develop a national polar-orbiting environmental satellite capability. This collaborative program will result in

significant long-term savings to the U.S. taxpayer through the elimination of redundant effort and the wise leveraging of research and development dollars.

Observing *networks* include weather radars, radiosonde stations, tide gauge and water level stations, volunteer weather observers, and numerous systems monitoring a broad spectrum of oceanic and atmospheric variables. NOAA constantly is designing, developing, testing and deploying new observing systems to improve its ability to monitor the environment.

NOAA finds it advantageous and cost-effective to cooperate with other agencies, with scientists and institutions in other nations, and with relevant international organizations. NOAA depends on other nations for access to their Earth-systems data and observations; for use of research facilities; for access to people and geographic areas; and for two-way transfer of technology.

- **Environmental Data and Information Services**

Services involving the acquisition, archiving, integration, and dissemination of environmental data and information are critical to the fulfillment of NOAA's strategic goals. NOAA maintains the largest environmental data archives in the world. New observational systems now coming on line will result in an exponential increase in the rate at which data is acquired, and will require sophisticated handling to ensure timely and useful data availability. NOAA must convey observations to many destinations for analysis and integration, process the observations into useful information products, and acquire and disseminate these products to users.

There hardly is a sector of the U.S. economy that does not rely to some extent on NOAA data and information services. By the year 2005, all NOAA environmental data and information products will be readily available to the Nation. NOAA information will be disseminated as part of the National Information Infrastructure. Products and services will be made available by nationwide networking connectivity at high data exchange rates using advanced information technology. NOAA's system of environmental information services will form an important link in the chain leading to informed policy decisions.

- **Supporting Infrastructure**

NOAA's supporting infrastructure consists of its workforce, facilities, administrative services, and public and educational services. All of these resources are essential to furthering the agency's strategic goals.

NOAA's greatest assets are its people. NOAA is committed to being the model employer of a talented, dedicated and effective workforce that reflects the Nation's diversity. This

includes the creation of a supportive work environment that encourages a respect for, and appreciation of, individual differences.

As all Government agencies streamline operations, the proper workforce skill mix becomes increasingly crucial. By 1999, NOAA will have reduced its workforce by 16% from the 1993 level. To ensure quality and performance while improving efficiency, NOAA must continue to invest in the training and education of its employees, make strategic hires, and implement innovative management practices.

Finally, NOAA must build and maintain facilities that are safe, energy efficient and in compliance with applicable laws and regulations. Facilities and sites requiring environmental remediation must be restored to a healthy and useable status.

THE STRATEGIC PLANNING AND BUDGETING PROCESS

The NOAA Strategic Planning and Budgeting Cycle is illustrated in the following figure. The cycle ensures the alignment of NOAA's strategic and programmatic objectives. It directs activities that allow the agency to plan, budget and continuously verify and validate performance.

Planning involves Teams comprised of representatives from all parts of the agency. The Teams are active throughout the strategic planning and budgeting cycle. From the Strategic Plan, the Teams create a 5-Year Implementation Plan. This Implementation Plan is updated yearly to maintain a realistic, yet challenging transitional course toward our vision for 2005. Programmatic priorities, level of accomplishments, and performance throughout the year are taken into consideration in developing policy guidelines, and in establishing key milestones and performance measures. NOAA's leadership, Line Administrators, and Program and Staff Office Directors utilize the milestones and performance measures to track progress toward meeting strategic goals and to formulate and update annual budget requests, one-year Operating Plans, and performance plans.

NOAA updates its Strategic Plan as required. Goals and objectives are reaffirmed or modified based on changing national needs, scientific and technological advances, and customer input. NOAA seeks extensive internal and external participation in reviewing and updating the Strategic Plan. This helps ensure that our goals, objectives and performance reflect the needs and expectations of the customers we serve.

CONCLUSION

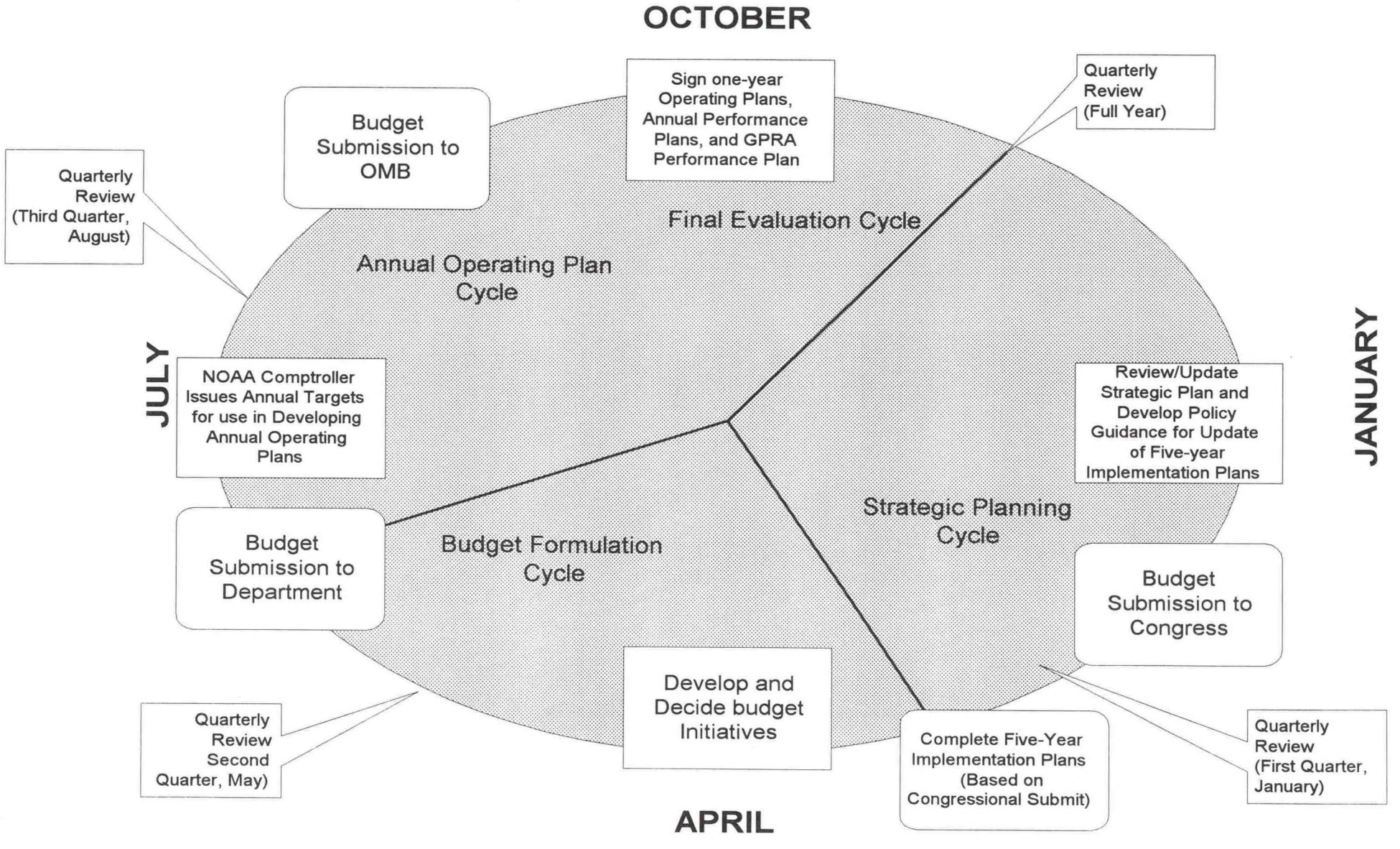
There are, and will continue to be, significant returns on investments made by NOAA. Our products and services pervade the daily personal and business life of every American. Our research and technology development ensures a continuing national capacity to solve problems and respond to change.

No other agency working in the natural environment has NOAA's responsibility for the measurement, monitoring and understanding of our atmospheric and marine systems. These are core businesses of Government, including functions which have highly concentrated costs and widely dispersed benefits -- such as the provision of weather warnings and forecasts.

The goals we have set for the future will enhance opportunities for our citizens, the health of the U.S. economy, the protection of our environment, and the sustainable use of our natural resources.

The following chapters describe in greater detail the goals and national capabilities which support NOAA's vision for the year 2005.

Strategic Planning Cycle



ENVIRONMENTAL ASSESSMENT AND PREDICTION MISSION

For 2005,
NOAA envisions integrated environmental observation, assessment, and forecast services that enhance public safety and the Nation's economic and environmental security.

ADVANCE SHORT-TERM WARNING AND FORECAST SERVICES

VISION

By early in the next century, NOAA will have significantly improved short-term warning and forecast products and services for a broad spectrum of environmental events (e.g., tornadoes, hurricanes, floods, tsunamis, and geomagnetic storms) that improve public safety and the economic productivity of the Nation. NOAA will attain this vision by:

- enhancing its ability to observe, understand, and model the environment;
- developing a total environmental prediction system; and
- effectively disseminating its products and services to various users.

THE CHALLENGE

Our environment has profound effects on our Nation's human welfare and economic well-being. Each year, hundreds of lives and billions of dollars are lost due to environmental events that could be predicted minutes to months in advance. Some are dramatic, such as the direct devastation caused by floods, tornadoes, hurricanes, coastal storms, tsunamis, and widespread droughts. Others have effects that are more indirect, such as the unnecessary contamination of fresh water supplies by runoff of chemicals into our rivers and lakes from day-to-day rains. Although nothing can be done to prevent the events themselves, expanded investments in NOAA activities will help to minimize their human and economic impacts.

NOAA's present ability to predict accurately short-term environmental change is restricted by observations that are incomplete in both time and space dimensions. This limits our ability to improve our understanding, and hence our predictive modeling, of the environment around us. NOAA has begun reducing the impact of environmental disturbances through a fundamental restructuring of the National Weather Service (NWS). However, improvements in NOAA's environmental prediction services cannot stop here. There is an urgent need for NOAA to re-invest in research components to improve its observational systems, develop a better understanding of environmental processes, and enhance predictive models and dissemination systems in a comprehensive approach for the total environment. Observations are a common element in operations and research and are an "enabling" requirement for NOAA's proposed improved services.

With 54% (as of 1991) of the United States' population residing in coastal areas, NOAA needs to strengthen its national capability to measure, understand, and forecast coastal and environmental phenomena that impact coastal economies, public safety, and environmental management.

NOAA has a unique opportunity to improve our Nation's total environmental prediction and warning capabilities. It must meet the challenges of saving hundreds of lives, averting thousands of injuries, and contributing billions of dollars to the economy by reducing our Nation's vulnerability to environmental disturbances.

Throughout NOAA, and in partnership with academia and other agencies, are the unique resources and talent needed to achieve the improvements in short-term prediction and warning capabilities outlined in this initiative. NOAA is the recognized national and, indeed, world leader in research supporting operational meteorological, hydrological, and space weather prediction and advanced instrumentation. NOAA is in the process of building the infrastructure of complementary observing, forecasting, communication, processing, data management, and dissemination systems needed to improve its existing strengths and expand its prediction expertise to other areas of the environment.

The charter for solving these problems is clearly NOAA's, but other agencies and the private sector will benefit from the products of the effort. Many federal agencies rely on NOAA to obtain the real-time observations and predictions needed to carry out their missions; and they, in turn, provide data that are essential to NOAA's mission. State and local governments distribute and use NOAA's predictions and warnings. The private sector disseminates and tailors NOAA's forecasts for an increasing variety of users who, as in the case of commercial airlines, provide NOAA with thousands of observations each day. Although all of these groups have vital roles in using and communicating the prediction and warning information to users, only NOAA can lead and coordinate the proposed improvement efforts.

SUMMARY OF OBJECTIVES

Advances in NOAA's operational atmospheric, hydrologic, oceanic, and space observing and prediction systems will immediately improve forecasts ranging from a few minutes to several months in advance. The improved observations and predictions are directed toward mitigating the adverse effects of the environment on our Nation's people, ecosystems, infrastructure, and economic processes. The following four objectives will ensure that NOAA attains its vision for short-term forecast and warning services:

Objective 1. ***Complete the modernization and restructuring of the NWS***

To date, experience with the NWS modernization has been extremely positive. This element will ensure that our past investments in technological development will be followed to fruition and that weather services will be maintained at a cost-effective level.

Objective 2. ***Maintain satellite continuity***

NOAA is responsible for maintaining continuous satellite coverage of the United States, adjacent oceans, and space environment. This element includes investments for geostationary

and polar spacecraft necessary to maintain continuous operational coverage into the first decade of the next century.

Objective 3. ***Enhance NOAA's environmental observing and prediction systems***

The NWS modernization represents only the first step toward providing an overall system of improved environmental forecasts. Additional service improvements through the U.S. Weather Research Program, Water Resources Forecasting System, Space Weather Program, and Coastal Forecasting System can occur only through a well organized research effort, including a combination of scientific, technologic, and programmatic advances. This will include research in the areas of predicting weather, water quality and levels for inland waterways, oceanic conditions, and the space environment. New observing systems will be developed, tested, and implemented to replace aging systems and to fill large data voids crucial to improving forecasts and warnings.

Objective 4. ***Improve service communication and utilization.***

NOAA will improve customer service to the public, emergency managers, water resource and ecosystem management agencies, the media, and private forecast planners through effective communication and utilization of NOAA's products.

Weakness in any of these actions will decrease the quality of all forecasts and warnings and their subsequent benefit to the environmental, economic and physical well-being of the population.

BENEFITS

SUPPORT OF NATIONAL GOALS

As we move into the 21st century, the challenge to NOAA and the Department of Commerce is to use and refine our capital investments, increase our understanding of the environment through research, and invest in critical new technologies to provide the accuracy and timeliness of forecasts that our Nation's population, ecosystems, and economy require.

NOAA plays a primary role in fulfilling the Administration's and DOC's goal of promoting stewardship of the global environment by providing accurate environmental forecasts and warnings to protect life, property, and commerce. The actions needed to reach this vision will create new high technology environmental observing, predicting, and information dissemination systems that support DOC's goals to open and expand foreign markets and increase U.S. exports and enhance technological development and commercialization.

The DOC and NOAA have begun to meet this challenge by implementing the NWS Modernization Program and the Water Resources Forecasting System, leading the

interagency U.S. Weather Research Program, and being a primary participant in developing the interagency National Space Weather Program. These programs are integral to the plans of the National Science and Technology Council (NSTC) Committee on Environment and Natural Resources (CENR) Subcommittee on Natural Disaster Reduction. NOAA will continue to implement these initiatives and other new environmental programs to provide the advanced environmental observations and understanding necessary to improve future forecast and warning services.

BENEFITS TO THE NATION

With our Nation's increasing dependence on and concern for protecting the environment, the payoffs of these improvements to the total environmental prediction system will be very substantial, even in the first few years of the effort. The benefits are many.

- Increased public confidence in local weather and hydrologic forecasts will reduce avoidable injury and property loss. This will be accomplished through improved forecasts and warnings delivered by an enhanced public dissemination system. This system will deliver additional advance notice to the public and other agencies for local hazardous weather including tornadoes, hurricanes, floods, drought, and intense winter storms over both land and oceans.

- Improved precipitation forecasts will enhance stewardship and management of inland and offshore water resources by providing advance products so that water resource managers can optimize the use of our inland and coastal waters and minimize adverse impacts due to floods and droughts. Forecast products will improve the safety and efficiency of maritime inland waterways and Great Lakes commerce and provide important information for maintaining and restoring environmental quality and improving fisheries management.

- Improved forecasts of space weather events, such as geomagnetic storms and solar flares, will allow better management of satellite operations, power generation networks, and satellite communication networks; and resulting mitigation efforts will reduce expensive damage to these systems.

- Increases in economic efficiency provided by more accurate outlooks of future environmental conditions beyond a few days will provide planning information for activities over land and water and in the near-Earth space environment. The sophisticated environmental technologies developed for monitoring these conditions will feed into new growth industries and help to maintain the Nation's status as a global technology leader.

- Expanded real-time observations and improved forecasting of hydro-meteorological and oceanic processes will reduce losses of life and property from extreme events through

advanced warnings of hazardous conditions; allow safer, more efficient navigation by commercial and recreational ships and small craft; and promote safer and better managed activities by commercial and recreational fishing industries.

Improvements associated with the NWS modernization alone will more than pay for themselves. The National Institute of Standards and Technology (NIST) cost/benefit analysis for the modernized NWS shows that the economic benefits to the Nation will be about eight times greater than the costs involved. Once the NWS modernization is completed, the Nation is expected to realize annual benefits of over $7 billion across various segments of the economy[11].

The potential benefits to the Nation will be measured in hundreds of lives saved, thousands of injuries averted, and literally billions of dollars saved. These benefits are extraordinary in comparison with the costs of this program. Some specific areas where improved observations and predictions will decrease our Nation's vulnerability to environmental disturbances include:

- Hurricanes: An average hurricane warning today covers about 300 miles of coastline and involves preparation and evacuation costs to the public in excess of $50 million per event. Improved predictions of hurricane tracks using enhanced observations will reduce the size of the warning areas, saving more than $5 million per storm. This is more than 50 times the cost of the proposed additional observations. Since the current necessary over-warning practices can lead to public complacency, the more accurate forecasts should be taken more seriously, thus saving lives and providing even greater savings from more thorough preparations. Some of the new observations will be provided by the NOAA Corps' new high altitude jet, which is expected to result in an immediate improvement in the accuracy of 24-48 hour predictions of storm track and better understanding of intensity change.

  The enhanced observations, coupled with the development of advanced models, will result in earlier, more accurate warnings. This additional preparation time will allow the public to protect residences better and relocate boats, recreational vehicles, etc., to safe locations. Such actions would save property owners and insurance companies several billion dollars over the course of a decade.

- Transportation System Operations: It is estimated that a 1% reduction in airline fuel consumption could save $100 million in fuel costs annually. Several times that amount could be saved easily each year through improved wind observations and forecasts provided by an enhanced global observing system. Substantial savings could also benefit the marine transport industry through improved ice and ocean current forecasts.

[11] *Benefit/Cost Study for the Modernization and Associated Restructuring of the National Weather Service* (U.S. DoC, National Institute of Standards and Technology, 1991).

The combined savings from these two user groups would significantly offset the cost of the global observing program.

- Inland Water Resources/Flood and Drought Mitigation: Most of the Nation's watersheds are managed to meet the needs of a variety of competing requirements such as flood control, water supply, transportation, fisheries, and hydroelectric power. Management decisions are sensitive to forecast accuracy and require lead-times of hours to days. The value of improved forecasts can be savings of billions of dollars per year. For example, in the Colorado River basin, an improvement of only 5% in the accuracy of water supply forecasts equates to an annual increase in hydroelectric power revenue of nearly $3 million dollars, not to mention the additional benefits to industry and agriculture.

  Advanced hydrologic prediction products will depict the magnitude of significant hydrologic descriptors (i.e., stream discharge and lake level) out to several months in the future. These products will greatly improve the capability of emergency and water facility managers to take timely and effective actions to mitigate the impact of major flood and drought situations. They will also provide better support for overall water resource management and sustainable development.

  In areas of the country that are susceptible to snow melt flooding, more accurate airborne measurements of the winter snowpack will lead to better management of reservoir storage, hydroelectric power, agricultural irrigation, and improved forest fire risk assessment.

- Geomagnetic Storms: In 1989, an intense geomagnetic storm left 6 million people in the Province of Quebec without electricity for 9 hours. A similar storm occurring during summer when power demand is great might black out the northeast portion of the United States. A Department of Energy study estimates the direct loss in gross national product could be as much as $3-6 billion. Timely and accurate geomagnetic forecasts will allow power distribution centers to adjust power loading to prevent damage and catastrophic power outages. Other sectors impacted include satellite systems for communication, navigation, and surveillance and high frequency and long-line transmission communication. Human safety during manned space flight or high-altitude aircraft flights could be compromised.

- Coastal Ocean Forecasts: As more people move to the coast, risks to life and property and economic harm due to coastal storms increase. Five times the number of people live in coastal areas now compared to 1900, with 112 million people residing in coastal counties. In addition to hurricanes and tsunamis, extra-tropical storms also cause significant loss of life and property. A series of coastal storms in 1982-83 caused $125 million in damages in California. The March 1993 "Storm of the Century" produced many more casualties than any recent hurricane, many due to unpredicted coastal

flooding. At sea, the Pacific Northwest Fishing Fleet loses an average of 30-40 lives and $60 million per year. Both categories of loss could be reduced by providing mariners with timely and accurate forecasts of severe weather. Improved oceanographic and meteorological forecasts are vitally important to marine commerce as well. For example, accurate and timely forecasts and warnings play a significant role in the offshore mineral exploration, development, and production industry, promoting finer scheduling and greater efficiency in operations.

- New Environmental Technologies: The observational technology component that is essential to the success of this initiative will also have an immediate and positive impact on our economy. For example, the advanced sensor research and development (R&D) proposed in this initiative will provide a substantial economic stimulus. The patentable observing technology, computer support, and data management systems required for these sensors are the "high tech" areas that will help our Nation to remain at the forefront of advanced environmental technology development. A real potential exists for new growth industries when these devices are developed and ready for commercial distribution in U.S. and international markets.

THE STRATEGY

RELATIONSHIP TO NOAA MISSION

This initiative contributes directly to several of NOAA's mandated responsibilities, most especially to promoting public safety and economic efficiency through environmental forecasts, warnings, and information.

The importance of this effort to improve public safety can be seen almost daily through television reports of the devastation and personal hardship wrought by tornadoes, floods, hurricanes, and the like. Though less obvious, the impact of fulfilling these objectives on the Nation's economic efficiency will be equally dramatic. For example, for a healthy, educated citizenry, more accurate precipitation and hydrologic forecasts from the modernized NWS will lower the environmental risks in food production by reducing ineffective applications and the unnecessary runoff of pesticides and fertilizers applied to crops. Runoff of these non-point source substances is the largest contributor of pollution to our Nation's lakes, streams, rivers, and estuaries.

OBJECTIVES

NOAA's current activities to provide prediction and warning services spread across and affect all of NOAA. The status of each major element is summarized below:

Objective 1. ***Complete modernization efforts***

NOAA is well under way toward completing the largest modernization and restructuring effort in the history of the NWS. Staffing and operational transition plans are being executed, new forecast offices are being built, and advanced systems are being deployed. New NEXRAD Doppler radar systems are in full-scale production for national implementation and have been installed at over 80 sites, providing increased accuracy to the NWS forecasts. Almost 68% of the required forecaster training has been completed. Data from a national lightning network have been acquired to complement the NEXRAD data. Over 50% of the total network of Automated Surface Observing Systems (ASOS) have been installed and are providing continuous observations. The contract for the development of the Advanced Weather Interactive Processing System (AWIPS) has been awarded. AWIPS will provide forecasters with the advanced workstation capabilities necessary to integrate large volumes of meteorological and hydrological information into a variety of forecasts and warnings. An intensive program to introduce field forecasters to the latest theories and techniques in meteorological and hydrological sciences has also begun. Although the modernization effort represents a major step forward, several years of additional activity will be necessary to take full advantage of the technological investments already made in the program.

During this decade, NOAA plans to advance and modernize its capabilities for collecting and processing observations and delivering short-term weather forecasts and warnings. The existing technological base for weather services is obsolete and costly to maintain. The NWS network of radars currently being replaced, for example, is already more than 30 years old. Obtaining some replacement parts is not possible. In addition, recent developments in technology and science offer an opportunity for improving weather and hydrologic service on a scale never before possible.

NOAA is in the process of implementing a new NWS field structure incorporating many improved technologies. Since this implementation must occur without disruption to the current service, it requires transitional activities such as new or modified facilities, staff augmentation, and training. These activities are considered part of NOAA's base program until the certification process required by P.L. 102-567 is complete.

The goal of NOAA's modernization and restructuring of weather and hydrologic services is to improve substantially forecasts and warnings. This goal will be achieved by the beginning of the 21st century through the following actions:

- Complete the deployment of NEXRAD Doppler radars and ASOSs. Installed across the nation, these systems will increase the accuracy and lead time for warnings for events such as tornadoes, severe thunderstorms, and flash floods.

- Install supercomputer systems at NOAA's National Meteorological Center. The new observations will be used to improve the temporal and spatial resolution of numerical forecast models that will be run on these systems.

- Install a full complement of AWIPSs for weather and hydrological services. They will enable forecasters to issue improved short-term forecasts and warnings.

- Restructure NWS field offices. Currently, there are 52 Weather Service Forecast Offices (WSFO), about 200 smaller Weather Service Offices (WSO), and 13 River Forecast Centers (RFC). The future field structure will include 119 Weather Forecast Offices (WFO) and 13 RFCs.

Objective 2. ***Maintain satellite continuity***

The geostationary satellite system is used to: (1) provide images of the United States, including Great Lakes and adjacent ocean areas, to enable detection of hurricanes and other major weather events for use in weather forecasts and warnings; (2) obtain quantitative environmental data such as temperature, snow and ice cover, moisture, and wind; (3) collect data from remote fixed platforms such as buoys and rain gauges for use in hydrological assessments and numerical weather prediction models; and (4) provide information on variation in the space environment and, on a future GOES J-M, x-ray images of the sun. The objective of this program is to ensure continuous satellite coverage through the procurement and launch of the geostationary operational environmental satellites (GOES). GOES-8, the first of a new series (GOES I-M), was launched in April 1994 and is now operational. GOES-9, launched on May 19, 1995, is also operational. The GOES I-M series has a five-year design life; however, the program is structured to have replacement satellites ready three years after the launch of the first two satellites, thereby enabling continuous coverage into the next century.

The polar satellite system is used to: (1) obtain quantitative environmental data such as temperature, snow and ice cover, and moisture used in numerical analysis and prediction programs; (2) locate and collect data from remote, fixed, and moving platforms such as buoys, balloons, and ships; (3) provide visible and infrared imagery and radiation flux of the earth and its environment; and (4) provide information on variations in the space environment. NOAA-12, launched in May 1991, and NOAA-14, launched in December 1994, are the current operational satellites.

NOAA's present ability to observe the environment is lacking in both temporal and spatial dimensions. NOAA must maintain essential, non-obsolete, existing operational satellite networks while developing new observational systems. The subsequent satellites, NOAA-J and the NOAA-K through N series, will provide polar orbiting satellite coverage through approximately 2004. During 1995, a tri-agency (NOAA, DOD, and NASA) program office began the definition and development of a converged polar orbiting system, which will

succeed the current NOAA satellites and DOD's Defense Meteorological Satellite Program. The systems will be used to acquire, independently verify, process, analyze, and distribute a wealth of new global data and derived products to a wide range of users. Activities also include research into developing follow-on satellite systems to support our needs for space-based observations of the Earth well into the next century.

Objective 3. ***Enhance environmental observations and predictions***

NOAA currently provides a variety of short-term predictions in the ranges of minutes to hours, days to weeks, and weeks to months, for the atmosphere, oceans and Great Lakes, surface water, and space environment. These efforts require a combination of national and global observing and communication systems, a central processing and computing structure, a program of applied research to support service improvements, and forecast offices to tailor the guidance to specific user needs to support the NWS mandate to protect life and property. New candidate observing components offer opportunities to improve the observing system and reduce costs.

Weather, water resource, space weather, and marine forecasts are prepared through a combination of local, national, and international observation and forecast systems, including outputs from numerical prediction systems tailored to specific forecast problems. Global weather models, used to forecast for periods out to weeks and months in advance, require a large mixture of satellite and conventional surface and upper air observations covering both the Earth's oceans and land masses. Regional models, used to provide one- to two-day forecasts of more detailed local events over the United States, supplement the global data set with a large number of finer scale observations, which can detect the development of small scale atmospheric and oceanic disturbances. Additional specialized fine-resolution models are available to provide guidance in specific locations for particular environmental events, such as the extent of coastal flooding due to hurricanes and intense winter storms or wind trajectories detailing the effects of volcanic eruptions and accidental nuclear power plant discharges.

The current NWS modernization efforts represent a first step at improving weather services, but the current accuracy of NOAA's full range of environmental forecasts and warnings needs to be improved through a directed R&D program. This cannot be carried out by NOAA alone; it must be coordinated with other Federal agencies, the universities, and private sector users of weather information. The needed coordination will be provided by the U.S. Weather Research Program, under the auspices of the NSTC/CENR. An analogous program, the National Space Weather Program, coordinates the improvements needed in space environment forecasts and warnings.

Under these programs, a number of limited, exploratory observational and forecasting improvement activities are already under way within NOAA research laboratories. Research includes:

- Improve severe weather forecasts. Initial research has demonstrated increased accuracy of severe weather forecasts when data sets from new observing systems are incorporated into prototype numerical prediction models.

- Develop advanced surface water forecast models. Hydrologic cycle research shows promise of improving streamflow and large lake water level forecasts in the weeks to months time frame.

- Develop technologies to improve coastal forecasts. Significant forecast improvements for both the onshore and marine environments are possible almost immediately if the data quality and quantity, and numerical models, are improved.

- Develop and assess new environmental observing systems. Research has led to the development and operation of an experimental network of 29 profilers to provide hourly observations of winds throughout much of the atmosphere. Wind profilers have proved to be very useful in operations and research. Other candidate systems are being examined in data assimilation experiments to determine the best-mix of cost-effective observing systems to operate in the future.

- Improve space weather forecasts and warnings. NOAA has shown that its space weather services can be significantly improved if a solar wind monitoring satellite is deployed between the Earth and the sun.

Although NOAA is making modest advances in improving its short-term monitoring and prediction of the environment, progress in developing and implementing new environmental observing and forecasting technologies has been slowed during the past 15 years due to reductions in research and development funding. NOAA plans to correct this deficiency to have a positive effect on operational service improvements well into the future.

NOAA will build upon and expand the observation systems being deployed as part of the NWS modernization and other programs, such as the Climate and Global Change Program, and provide the research and development crucially needed to improve NOAA's understanding and short-term modeling of all environmental phenomena. The result will be a prediction and warning system for the early 21st century that has been built upon a cost-effective and balanced mix of environmental observations, understanding, and modeling. NOAA will achieve these goals through the U.S. Weather Research Program, Water Resources Forecasting System, National Space Weather Program, and development of the Coastal Forecasting System. Specific tasks include:

- Advance NOAA's observational systems

  In collaboration with other laboratories and industry, NOAA plans to implement an instrument development program dedicated to atmospheric, coastal marine, and solar-

terrestrial observations. It will combine expertise in using seagoing, ground-based, airborne, and satellite platforms and will develop advanced techniques including both direct and remote sensors for use on these platforms. These techniques will be designed to address the broad environmental observing issues and will complement the global observation systems proposed by NOAA and the world climate community. By linking this new capability with existing advanced data management, data assimilation, and modeling efforts, NOAA will ensure compatibility and adherence to future environmental observation system concepts.

Obtaining the basic environmental observations needed for accurate predictions requires a complex array of direct sensors and ground- and satellite-based remote sensing technologies. No single observing system can accomplish this task. When measurements from these systems are combined, NOAA will have, for the first time, the increased spatial and temporal resolution of data necessary to improve model forecasts. The observing systems proposed in this initiative will by no means saturate our environment with observations, but they represent a prudent plan to fill critical gaps in the data sets essential for extending the range of forecast improvements across the environment. Developing this future observing system will be accomplished with the following major actions:

- Develop an integrated upper-air observing system covering local to global scales. This system will be based on the optimum combination of existing and new sensors deployed on a variety of available and planned platforms. The operational data bases will form complete four dimensional, high resolution fields of all relevant parameters such as winds, temperature, and humidity. Developing such a system for the 21st century will require four thrusts: (1) replace outdated and deteriorating parts of the current land-based upper-air sounding systems with cost-effective technologies to preserve the foundation of the current observation and prediction capabilities; (2) establish a long-term program to assist decisions in arriving at a best-mix for the observing system; (3) deploy new, automated remote and direct sensors, as well as the platforms needed for these sensors, to provide better spatial and temporal observations of the upper atmosphere. NOAA will pursue efforts to capitalize on the use of interdepartmental (DOD and DOC) cooperative efforts such as the National Ice Center to improve forecasting and research of ice and polar regions. Access to classified observing systems developed for the Defense and Intelligence communities will also be pursued; and (4) develop, assess, and deploy new remote sensing technologies and specialized direct measurement platforms to provide observations in data-void regions or when hazardous events, such as hurricanes, threaten. Operational improvements are possible because of sustained R&D activity in the past. Continued strong R&D is our only hope for future improvements.

- Develop and deploy direct and remote sensors capable of monitoring the terrestrial and marine environment. These observations are incredibly sparse and must be increased substantially by the end of the decade. Activities include increasing the number of advanced atmospheric, hydrologic, and oceanic observations in our inland, offshore, coastal, and Great Lakes waters. These systems will provide essential observations of surface weather conditions, water level and temperature, ice cover, currents, and wave heights. Efforts will also focus on developing remote sensors that will further enhance our observations of the marine environment.

- Enhance the solar-terrestrial observing system. This will be accomplished by obtaining data from a real-time solar wind monitoring satellite that will enable approximately one-hour warnings of an impending geomagnetic storm. NOAA will also take advantage of new data sets obtained from other agencies' space environment sensors to provide the anticipated service improvements as soon as the data are available.

- Advance NOAA's environmental prediction systems

Data sets from the observational systems currently being deployed as part of the NWS modernization and those described in this section will support significant improvements in NOAA's ability to predict the environment days to weeks in advance. These improved observations alone are not enough. NOAA's prediction capability must also be enhanced through a combination of focused observational studies of environmental behavior, theoretical analyses, model development, and research projects. This work will rely on advanced observational techniques in combination with existing data sets to fill in critical knowledge gaps. As our understanding of environmental phenomena increases, this knowledge will be incorporated into research and prediction models, which will undergo rigorous testing prior to operational implementation.

In the past, NOAA systems have tended to focus on specific problems and to be only weakly linked to other components of the environment. For example, NOAA's atmospheric models use sea surface temperature data, but these data are not allowed to change as the forecast progresses. Initial results from a coupled ocean/atmospheric model that links the entire environmental system under one prediction umbrella are showing improved specific forecasts and proving that forecasts from a single integrated system can meet the needs of a much broader user community. Cooperative research efforts among DOD operational processing centers and the National Meteorological Center will also provide advances in coupled air-ocean modelling to improve an umbrella prediction system. These initial research results will set the foundation for the integrated prediction systems needed in the 21st century.

Specifically, the following actions will be undertaken:

- Advance our fundamental knowledge of the environment. NOAA will increase its understanding of the wide spectrum of processes that govern variations in the atmosphere, hydrologic cycle, oceans and lakes, and space environment on local to global scales. This will be accomplished across a variety of NOAA research laboratories through acquisition, analysis, and study of local to global scale data sets and, when necessary, periodic field programs.

- Utilize new observations and knowledge to improve data assimilation and predictions. Improving data assimilation techniques will help us exploit more fully current observations and design the most cost-effective future composite environmental observing systems. Because data assimilation is the means for inserting observations into numerical prediction models, improving data assimilation will also lead to better forecasts. NOAA will also develop and assess new prediction models, especially those that link environmental systems such as the oceans and atmosphere or the atmosphere and land surface.

- Apply the newly-gained understanding and prediction models to forecast operations. This will be accomplished by developing local analysis techniques and predictive models, evaluating and assessing the reliability of new forecast tools and procedures, and increasing collaboration among the broader research community and operational forecasters. Risk reduction and demonstration projects will be conducted to smooth the transfer of warning and forecast improvements to NOAA's operational services.

Objective 4. ***Improve service communication and utilization***

NOAA's current meteorological data distribution systems rely primarily on voice and text broadcasts. For example, the NWS uses several primary means to disseminate information to its users. They include the satellite-driven, nationwide "Weather Wire" and the telecommunications "Family of Services," both of which provide hard copy via user printer and/or computer, and the nationwide (but not fully completed) "Weather Radio" network of very high frequency broadcasts. Other users depend on the still widespread use of manual telephonic communication, the Federal Emergency Management Agency's manual telephonic National Warning System (NAWAS), and bulletin board-type two-way computer links with specialized users in the marine and aviation communities.

For further dissemination of its information, NOAA relies on the media and emergency managers to reach the general public, the Coast Guard to reach marine interests, Air Route Traffic Control Centers and Flight Service Briefing Centers to reach aviation interests, and NIST radio to reach users of space environment data. Many of NOAA's dissemination mechanisms are outdated, with some transmitters still relying on "tube technology." New, more useful and rapid graphical display capabilities are being developed and tested in

NOAA's Weather Dissemination System, which will improve the application and dissemination of NOAA's products and services to enhance public safety.

The benefits of NOAA's planned improvements in short-range predictions and warnings will fail to meet their full potential unless the information can be retrieved and passed quickly and clearly to our various customers. As public confidence in our predictions and warnings increases, we must provide information to the public in the quickest, clearest fashion. Tornado, flood, hurricane, coastal, and other critical environmental warnings are often hard to access when they are most needed. Frequently, the information is available only at a few locations via low-speed teletypes or telephone. Recent events have underscored the severity of the problems associated with these archaic communication systems. The situations range from the nationally visible lack of preparation for emergency actions before the well-forecast landfall of Hurricane Andrew to avoidable losses in agriculture, transportation, and energy management through incomplete access and understanding of NOAA's full environmental data base.

NOAA plans to improve its dissemination system over the next five years through implementation of the NOAA Weather Dissemination System. This system will use advanced AWIPS-type data at each local NWS Forecast Office to provide high-resolution user-friendly graphical displays to public officials. This timely, accurate weather information will be provided via a community file server that local government and state agency officials can assess to make informed decisions on the protection of life and property, and the optimal use and protection of our natural resources. This advanced weather information will be integrated with geographical data from local sources and action rules from the emergency management warning plans to compute assertions (weather characteristics related to spatial and temporal objects) that are important to the community. This decision support system constantly monitors weather hazards and can alert government officials to the potential impact of severe storms, flash floods, wildfire, hurricanes, and winter storms. Additionally, NOAA's Weather Dissemination System can assist users with drought data for crop estimations, disaster planning, and atmospheric wind and coastal/river current information for transportation planning to meet the wide variety of public needs. NOAA will work in partnership with the private sector through mechanisms such as Cooperative Research and Development Agreements, to design and develop the hardware and software associated with the NOAA Weather Dissemination System, including integration with existing emergency management decision support systems. Once development is complete, the technology will be made available to the private sector for implementation nation-wide.

CONCLUSION

The environment will always have profound effects on our Nation's human welfare and economic well-being. Although we can do nothing to prevent natural disturbances, we must do everything possible to minimize their human impact. The actions planned by NOAA to improve its observing and predicting capabilities represent a long-delayed comprehensive

move toward a greatly improved ability to deal effectively with the Nation's environmental issues. The enhanced ability to monitor, understand, and predict environmental phenomena is the essential base upon which we can begin to set sensible environmental policy, make informed management decisions, and enhance the safety and well-being of our population.

IMPLEMENT SEASONAL TO INTERANNUAL CLIMATE FORECASTS

VISION

NOAA will provide one-year lead-time forecasts of known skill of global climate variability, initially focussing on the El Niño-Southern Oscillation (ENSO) phenomenon and its effect on global precipitation and surface temperature distributions. NOAA will be responsible for making these forecasts available in the United States and will participate in a multinational effort to distribute them worldwide. Forecasts can provide society with a mechanism to act on the basis of anticipated climate fluctuations, respond to mitigate against economic losses and social disruption, and exploit economic opportunity.

The actions described lead to an operational program for the systematic production and application of regionally tailored climate forecasts. Seasonal to interannual climate predictions represent a major new contribution for sustainable development by offering opportunities to manage natural resources more effectively and improve the quality of human life, especially for those living in regions most vulnerable to the impacts of climatic variability.

THE CHALLENGE

Society is accustomed to dealing with climate variations, but as human population grows and the pressures on society's infrastructure increase, society becomes increasingly vulnerable to unanticipated departures from the norm. Activities such as agriculture, fishing, water management, and fuel distribution take into account the climatological mean annual cycle; crops are planted in anticipation of the optimal growing season; fishing vessels in Peru and Oregon are readied for the seasons when wind-driven upwelling provides nutrients for the food chain; reservoir levels are lowered in anticipation of spring flooding; fuel oil is distributed in anticipation of wintertime heating needs. Commerce and industry have evolved to function optimally to accustomed seasonal changes, and in the absence of a forecast, the best society can do is to prepare for "normal" seasonal trends. With long-term climate forecasts, society can respond to reduce the disruption, economic losses, and human suffering that occur in response to changes in the annual climatological cycle.

A primary objective of this effort is to implement the operational facilities required to provide routine, continually improving predictions of ENSO events and the consequent changes in oceanic and atmospheric climatic conditions using dynamical models and to deliver forecasts based on these predictions to the global community of users. This effort will require a permanent observing capability for those ocean and atmospheric observations required for the predictions and a strong research program in modeling and process research to improve the forecasts. This plan to implement seasonal to interannual climate forecasts, initially based on ENSO, is a NOAA-led effort to reap the benefits of our investments in

research. The objectives address the need to obtain societal benefits from that research. Coupled with analysis of how human behavior can incorporate climate information, forecasts have clear societal and economic benefits.

This program addresses the predictability of seasonal average variations in the climate system, which results from coupled interactions of the ocean-atmosphere-land system. Unlike the intraseasonal variability in temperature and precipitation that is inherently difficult to predict more than a week in advance, these seasonal averages exhibit predictability that extends out a year or more. The ENSO phenomenon is the largest component of interannual climate variability that has a degree of predictability. During an El Niño event, the pool of warm water that is normally found in the western Pacific expands eastward, carrying with it portions of the rainfall normally found in the far western Pacific. This shift in the distribution of tropical deep convection leads to shifts in jet stream tracks, resulting in climatic anomalies around the world. In the United States, an ENSO warm episode causes warmer than normal winters in the northwest, while at the same time below normal rainfall is likely to occur in the Gulf Coast states and below normal rainfall in the mid-west with drought conditions along the southeast coast. Drought conditions are also to be expected in late fall and some winter months in the Pacific northwest. Pacific fisheries catches from Chile to Alaska are decreased or displaced by the change in water temperature. Increased frequency of forest fires has been associated with the cold phases of ENSO due to low precipitation in many areas; hurricanes also are believed to increase during a cold event. In 1992, increases in wheat prices and shortages in fish oil were attributed to El Niño-induced climate changes.

Prediction of change on seasonal and interannual time scales is still an emerging research area, as is research on social impacts and vulnerability to climate fluctuation. Nevertheless, remarkable initial successes have been achieved. It is now possible to predict the temperature changes in the tropical Pacific associated with ENSO events, and statistical and dynamical forecast tools are being developed to relate these to changes in climatic conditions such as rainfall levels at other locations. The focused ocean-atmosphere environmental research in the decade-long, multinational Tropical Oceans Global Atmosphere (TOGA) program has produced the ability to detect and predict critical environmental changes connected with ENSO. ENSO events affect rainfall and surface temperature distributions, and atmospheric and oceanic circulation; hence, the most affected economic sectors are agriculture, natural resources management, fishing, water resources, and energy, although construction, recreation, and transportation might also be greatly influenced. Various estimates place the annual value of a reliable 6-12 month advance notice of an ENSO event in the range of several hundred million dollars for the U.S. agricultural sector alone; estimates for all sectors approach 1 billion dollars[12]. The cost to the Nation of making these observations and predictions is repaid several fold in the mitigation of losses in our

[12] *Toward a Global Ocean Observing System: The Case for GOOS,* IOC/INF-915 (IOC, UNESCO, Paris, France, 1993).

agriculture and energy sectors. In addition, our contribution to stability and improvement of the global economy will be substantial, especially in South America, Africa, India, Southeast Asia, and Australia where ENSO impacts are considerable.

NOAA plans to provide climate services to meet the diverse needs of users. This program will produce both predictions of climate, defined as objective projections of future conditions obtained through statistical or dynamical models, and forecasts, defined as the synthesis of predictions suitable for application by the user community. The format of a purely technical prediction will most likely not meet the needs of users in different economic sectors. Therefore, it is equally important to invest in the delivery of forecasts and associated applications. The forecasts will provide information to users on anomalous variations of temperature, rainfall, and ocean circulation patterns. It is likely that they will be averages for large regions and for a season, especially over North America. The skill of the forecasts will depend strongly on the location and season of the year. Nevertheless, initial experience and analyses show that even with this information, substantial social and economic benefits can be derived.

NOAA alone cannot address all the requirements of an operational prediction program. U.S. efforts in climate research are coordinated under the National Science and Technology Council (NSTC) Committee on Environment and Natural Resources (CENR). International participation is also required, and the U.S., through NOAA, is taking the lead in establishing the required partnerships with a proposal to launch a Seasonal to Interannual Climate Prediction Program (SCPP). This program will lead to the establishment of multinational mechanisms for generating and disseminating useful climate information and forecasts. A fundamental component of this program is the establishment of a network of centers operating on behalf of countries interested in or affected by climate variability. Operational forecasts in the United States will be produced at the NWS National Centers for Environmental Prediction. The plan for Operational Climate Forecast Services (OCFS) for the U.S. community has been prepared by the National Weather Service and the Office of Global Programs (OGP). (Both plans are available from OGP.)

SUMMARY OF OBJECTIVES

ENSO predictions have been made primarily on an experimental basis, using the tools, facilities, and funds of the research community, with strong and long-term support from the NOAA OGP. NOAA aims to build on this research experience, to make use of the decades of investment in research, so that the Nation can realize the potential societal and economic benefits. Four program activities are necessary to implement seasonal to interannual climate forecasts and to derive the associated social and economic benefits.

Objective 1. ***Implement prediction systems***

NOAA plans to provide improved predictions and forecasts of seasonal to interannual variations in surface temperature and precipitation to enhance economic opportunity and social benefits. Until recently, forecasts were based on statistical tools. NOAA is in the process of extending the lead time of forecasts for the U.S. through the use of predictions from dynamical models of the ocean-atmosphere system. Operational use and improvement of these models, together with improvements in the delivery of climate forecast services, will be required to enable the Nation to obtain the maximum benefit from these forecasts. Enhanced international outreach for experimental predictions, research and development, applications, and training is needed.

Objective 2. ***Maintain and improve observing and data delivery systems***

NOAA plans to implement the observational and data systems required for the predictions, assessments, and underlying research efforts. The core part of the observing component is the TOGA observing system. This system needs to be optimized for prediction purposes and its support stabilized. Data systems need to be updated to handle additional access and the enhanced data flow resulting from the modernization of the data systems for all components of NOAA's activities.

Objective 3. ***Conduct research for improved climate predictions***

NOAA plans to perform the research necessary for continuous improvement of the predictions and to expand beyond the initial TOGA focus in the tropical Pacific to include the other tropical oceans, mid-latitude oceans, land surface processes, and impacts on living marine resources. Furthermore, ENSO is not the only climatic variability on seasonal to interannual time scales. NOAA will look beyond ENSO events to study and ultimately predict other aspects of climatic variability and to assess the combined influences of these events on the physical, biological, chemical, and hydrological environment.

Objective 4. ***Deliver climate services and assess socioeconomic impacts***

NOAA plans an organized effort, both nationally and internationally, to develop the applications to ensure that the user communities benefit from the improved forecasts. NOAA will work with states and the private sector to establish state environmental application centers to facilitate the communication between forecasters, users, and private industry. Internationally, NOAA will assist in training and establishing application centers through the SCPP.

BENEFITS

SUPPORT OF NATIONAL GOALS

Prediction of interannual climate variability and the resulting environmental change is a direct, major contribution to the U.S. interests in economically efficient environmental policy, including commitments made at the United Nations Conference on Environment and Development (UNCED). This program responds strongly and affirmatively to the DOC interest in our combined focus on environmental health and economic efficiency. Climate forecasts directly address the DOC mission by working to ensure economic opportunity and to promote stewardship of the global environment. In addition, the development of the observing components requires a close partnership with U.S. industry. This program is also a principal U.S. contribution to the World Climate Research Program, Global Ocean Observing System (GOOS), and Global Climate Observing System (GCOS).

Climate predictions also are a major new tool for sustainable development. They offer opportunities to more effectively manage natural resources and improve the quality of human life, especially for those living in regions most vulnerable to the impacts of climatic variability.

BENEFITS TO THE NATION

Initial estimates of the consequences of ENSO in the U.S. and around the world indicate that El Niño events have strong implications for economies, human health, and the quality of life. A broad range of users and a substantial segment of the U.S. economy stand to benefit from interannual climate forecasts, including the agricultural, fishing, forestry, energy, insurance, public health, water resources, recreation, transportation, health, and construction sectors. The U.S. food system, for which agricultural productivity is the core, is particularly sensitive to climate fluctuations and contributes over $820 billion to the U.S. economy. In each case, prior knowledge of the onset and intensity of the next season's or next year's climate fluctuations can lead to far more efficient decision making. Several studies have found substantial economic value associated with improved climate forecasts:

- A 1986-87 ENSO event, which has been associated with the subsequent northern hemisphere drought of 1988, led to a significantly reduced crop yield, increased disaster assistance payments, higher food prices, and disrupted transportation on internal waterways. According to a study by SCI, Inc., an agricultural consulting firm, losses for non-farm, down-stream agribusiness amounted to $10-15 billion. When the total of impacts upstream and downstream from the farming sector are taken into account, the drought experience in 1988 is estimated in one study to have cost the economy $28-44 billion.

- Another study, which valued core U.S. agricultural activity at $95 billion for fiscal year 1992, estimated that at least 10% of the sector value is lost due to an ENSO event, but that 15-20% of that loss could be mitigated through use of climate forecasts that are accurate 75% of the time. This suggests a loss mitigation (savings) of $4 billion due to ENSO forecasts over a 12-15 year period for the U.S. agriculture sector alone.

- Based on a probability of 60% to predict a warm event at least six months in advance, the potential savings for the U.S. agricultural sector could be $0.5-1.1 billion per event. The average value of annual savings would be $183 million per year over a 12-year period. Assuming that ENSO forecasts become even more accurate, to a probability of 77%, additional mitigation in the U.S. agricultural sector could increase annual savings to $313 million per year. The impacts on marine fisheries were estimated to be $20 million per year[13]

- The Intergovernmental Oceanographic Commission (IOC) has estimated that the economic benefits of these forecasts approach $1 billion/year across all economic sectors[14].

Case studies have proven that human societies respond favorably to accurate and timely ENSO forecasts; the responses result in reduced economic damage both within local economies and across trading economies. For example, in the Brazilian state of Ceara, agricultural officials used the predictions of the 1991 ENSO conditions to change the timing and types of crops planted. That year the state had harvests at a near normal level, compared with massive crop failures during the 1987-88 ENSO.

Benefits to the water resources and energy sectors are potentially as large as those for agriculture, depending upon how forecast information can be integrated into risk assessment. The availability of fresh water for irrigation and household use is fundamental to the Nation's economic well-being and varies drastically during an ENSO event. Decisions on the purchase and distribution of fuels could be made more cost effective, or estimates of fuel demand based on anticipated climate trends could contribute to more efficient decisions regarding options for purchasing different energy supplies.

This program will provide further analyses of social and economic vulnerability to climate variability; how individuals and institutions can incorporate improved forecast information into adaptive strategies will provide the information required for full realization of the benefits of predictive knowledge. Although economic benefits derived from the use of

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[13] *Workshop on the Economic Impact of ENSO Forecasts on the American, Australian, and Asian Continents* (Florida State University, February 1993, Available from NOAA Office of Ocean and Earth Sciences).

[14] *Toward a Global Ocean Observing System: The Case for GOOS*, op. cit.

climate information will vary from year to year, conservative estimates place the average value of an ENSO forecast at $1 billion annually in terms of mitigated losses (including jobs saved and social disruption minimized) in the U.S. economy. Globally, the estimate of the value of ENSO forecasts exceeds several billion dollars.

THE STRATEGY

RELATIONSHIP TO NOAA MISSION

The DOC is responsible for providing basic meteorological services and supporting research to the general public. Within DOC, this task has been given to NOAA. For shorter time scales, this task is described in the chapter on Advance Short-Term Warnings and Forecast Services. NOAA will capitalize on new understanding of multi-season climate phenomena in its goal to Implement Seasonal to Interannual Forecasts, with the objective of making the assessments and forecasts needed to maintain the Nation's economic strength. The NSTC/Committee on Environmental and Natural Resources, Subcommittee on Global Change, coordinates the climate research by U.S. agencies and assigns NOAA responsibility for in situ and satellite observation and monitoring programs; mission-directed research on physical and biogeochemical processes in the climate system; development, testing and application of models, and maintenance and distribution of long-term data bases of climate information.

Predictive capabilities are also essential to NOAA's mission of environmental stewardship in that the potential effects of climate change and variability aggravate present environmental problems and add another dimension to their complexity.

OBJECTIVES

These objectives are envisioned to lead to an operational program for the systematic production and application of regionally tailored climate forecasts. They represent an end to end integrated approach, involving prediction systems, observing and data systems, research, and applications to address the establishment of such a system.

Objective 1. *Implement Prediction Systems*

NOAA, through its Climate Prediction Center (CPC) of the National Centers for Environmental Prediction (NCEP), currently provides operational seasonal forecasts based on a combination of dynamical model and statistical predictions for up to one year in advance for the U.S. NOAA is also responsible for operational climate monitoring and diagnostics, model development, and computational support. Extramural programs supporting these activities include many collaborative efforts with the academic community, other agencies, and states. Seasonal forecasts for the United States are widely distributed by the Climate

Analysis Center (CAC). NOAA will continue to work with states and the private sector to disseminate the forecasts, a wide variety of monitoring products, and data sets.

NOAA plans a two-track program to integrate national and international delivery of useful seasonal to interannual climate forecasts. NOAA will provide operational climate forecasts for the United States national community, and the parallel multinational effort will assist the international community in generating and using these forecasts. The need for a two-track integrated effort is clear: for reasons of national security and economic advantage, the U.S. needs an official climate forecast from a federal source (NOAA) and a facility that is fully funded and managed by the U.S, with complete autonomy in, and responsibility for, the development and use of its own forecasts. The National Centers for Environmental Prediction (NCEP) are responsible for the official U.S. government climate forecasts.

NOAA will enhance its national operational forecasting capability. The NCEP will launch an OCFS program to accelerate development and implementation of a multi-season prediction system, based upon coupled ocean-atmosphere models to supplement the current forecasts that use statistical techniques, such as:

- Operational climate prediction - (1) accelerated development of a multi-season forecast system based upon coupled ocean-atmosphere models, (2) operational implementation of a coupled forecast system, and (3) integration of the product suite into the activities of the Climate Prediction Center.

- Data processing and access - expansion of the development and implementation of systems to process and assimilate observations and to produce the product suite and supporting data sets.

Equally important, because many developing nations do not have the scientific and funding resources required to establish their own climate forecasting institutions, the U.S. plans to participate with other nations in the research and development on, and use of, seasonal to interannual climate forecasts, as it committed at UNCED. In parallel with these activities, NOAA will initiate the SCPP, a planning process intended for the early establishment of a multinational system to generate and transfer climate information and forecasts to the world community. The essential prediction-related activity for this focus is the International Research Institute (IRI), a network of research centers to be established for SCPP at existing research institutions; one or more of them will be established as the host site for the IRI. The IRI will be responsible for generating and distributing experimental forecasts in other countries.

Cooperative interaction between the NOAA/NCEP and IRI for SCPP is a critical element of NOAA's planned integrated prediction system. Such interaction will include providing feedback on the quality of data and products exchanged, offering advice on optimization of data platforms, and exchange of forecasts for research use. Rather than developing

independent and duplicative data processing efforts, the IRI will receive much of its atmospheric and oceanic data from NCEP and other worldwide operational global forecast and data management centers. NCEP and IRI will also seek collaboration in development of models, initialization schemes, and forecast methodologies. The interests of NCEP and IRI are highly complementary, and interaction will be mutually beneficial.

Objective 2. ***Maintain and improve observing and data delivery systems***

NOAA supports observing programs that collect the data necessary for seasonal to interannual climate forecasts. They include both in situ measurements (winds, sea surface temperature [SST], upper ocean temperature, sea level, and currents) and satellite measurements (SST, sea level, outgoing long-wave radiation, oceanic aerosols, and precipitation estimates) as well as annual assessments of ice conditions.

NOAA has a statutory responsibility for maintaining the Nation's weather and environmental data. This responsibility goes beyond the requirement for a seasonal to interannual climate prediction goal and supports many other aspects of NOAA's program. For simplicity the data management activities of the NOAA National Data Centers and line offices are all included under the Seasonal to Interannual goal. The Centers collect, process, archive, and disseminate data and information, generate informational products, and provide long-term data storage and stewardship. The Centers also provide a customer service facility and some on-line access to metadata and data sets. Other key data center activities include rescuing critical environmental data at risk of being lost due to deteriorating storage media and providing the archiving and accessing capability for data from new NOAA observation systems. User access to NOAA-wide data and information is also available through the NOAA Directory Services, e.g., the NOAA Data Set Catalog.

NOAA has invested in the development of several baseline data sets, including the Comprehensive Ocean Atmosphere Data Set and the Comprehensive Aerological Reference Data Set. They play a major role in defining and understanding past climatic variations. Data quality and continuity must be assured to provide users with products depicting real trends rather than artifacts of changing observing systems or practices.

- Transform the TOGA Observing System (TOS) for Operational Use: A 1994 report from the National Academy of Sciences, "Ocean-Atmosphere Observations Supporting Short-Term Climate Predictions," identified the measurements necessary for making climate predictions on seasonal to interannual time scales, based on current scientific understanding. In priority order these are: surface wind stress, sea surface temperature, upper ocean thermal structure, sea level, upper ocean currents, and upper-air observations (World Weather Watch [WWW] system). Many of these measurements are now being collected by the TOS, a research funded program involving primarily in situ observing systems in the tropical Pacific. New funding is being sought to provide the long-term operational support to transition TOS to routine

use for climate predictions. U.S. GCOS and GOOS planners also have identified the TOS as a priority element for the GOOS Climate Module. As that funding becomes available, TOS will become a principal U.S. contributor to GCOS/GOOS.

The TOS has five elements: (1) Tropical Atmosphere Ocean Array, (2) Surface Velocity Program, (3) Voluntary Observing Ship Expendable Bathythermograph Program, (4) Indo-Pacific Sea Level Network, and (5) Trans-Pacific Profile Network. These in situ measurements are complemented by a number of satellite-based systems, including AVHRR (SST), active microwave scatterometry (surface wind velocity), and radar altimetry (sea level). NOAA's AVHRR provides global views of SST, which are essential for documenting climatic variability and prediction. Winds from the European Space Agency's ERS-1 scatterometer will soon be routinely assimilated into operational atmospheric models and will be supplemented with scatterometer data from Japan's Advanced Earth Observing Satellite (ADEOS). Sea level observations from the U.S./ French Topex/Poseidon altimeter mission are beginning to be assimilated into ocean models and used in prediction experiments. The WWW must be enhanced to provide upper-air observations over the oceans, particularly in the tropics.

The operational observing system must be built to balance the strengths and weaknesses of the ground and space-based measurement systems. For example, satellite-derived SSTs require continuous and widespread correction by in situ measurements by ships and buoys. Thus the observing system must include in situ SST measurements from all oceans. Similarly, altimetric measurements of sea level need to be validated on a routine basis by a network of tide gauge measurements.

In order to transform what is now a research-based observing system into a routine activity, the in situ portion of the TOS must be maintained (possibly expanded in certain key areas, as research indicates) for at least 5-10 years. This will require the close collaboration of the research and operational components of NOAA as a gradual transition to operational status is made. Studies will made to examine the trade-offs between the various components of TOS and how they contribute to forecast skill in order to optimize the system.

- Research Observations and Data Sets: In addition to data sets required primarily for prediction, in situ and satellite observations are required to support the Global Energy Water Cycle Experiment (GEWEX), the Global Ocean Atmosphere Land System (GOALS) Program, and modeling research programs. In situ or ground-based systems will be developed as part of the research programs and, as their long-term utility is demonstrated, can be transitioned into operations. Many remotely sensed parameters can be obtained from NOAA's operational satellites if a commitment is made to producing climate products from sensors currently used to support short-term warnings and prediction; climate products require development of retrieval algorithms and intra-

satellite calibration procedures for climate. Research satellites provide additional information.

Products from both types of satellites include land surface (snow cover, surface radiation parameters, and land surface temperature) and atmospheric products (global distributions of precipitation, water vapor, cloud liquid water, and cloud and radiation budget parameters). Ocean products include information on sea ice from synthetic aperture radar and observations from ERS-1; Radarsat and ocean color data will be available from SeaWifs and ADEOS. The sensors used for ocean color also provide information on atmospheric aerosols, which are a limiting factor in current satellite-derived SSTs. With the right algorithms, and suitable in situ calibration, ocean color data can provide critical global information on spatial and temporal variations of phytoplankton biomass and productivity. Such information is central to studies of the impact of ENSO on coastal and oceanic fisheries.

- Improved Data and Information Systems: In order to improve NOAA's data systems so that high quality, multidisciplinary data sets and products can be routinely generated and made accessible to researchers, policymakers, and the public, NOAA's present environmental data and information system needs to be extended:

  - To facilitate data flow to NOAA researchers and the broader research community, better connections need to be developed within NOAA and the outside linking the widely dispersed holding to form a uniform, logical data system for NOAA and the global climate community.

  - Better data and information access systems need to be designed and implemented to expedite users' interaction with the relevant data sets from different disciplines, thereby promoting interdisciplinary research.

  - An enhanced capability is required to ingest, quality control, and make accessible the full range of NOAA's data and information, including the large volume data sets from the in situ and remotely sensed observational systems including geostationary and polar orbiting environmental satellites (GOES and POES) and the next generation weather radar (NEXRAD).

  - Improved data systems are required to provide timely data and environmental information products relevant to a wide spectrum of local to global resource development issues.

  - Historical data sets need to be made accessible and used in reanalyses of the ocean and atmosphere. These reanalyses use dynamical models and data assimilation systems to provide dynamically consistent fields for climate documentation and diagnostics.

Two major activities, Environmental State Indicators and the Satellite Active Archive (SAA), address aspects of these problems. NOAA has developed several environmental state indicators in response to requests for information relevant to the state of the environment. These indicators need routine updating and dissemination. The SAA provides on-line access to operational satellite data and information products. The SAA serves users who require access to daily, monthly, and multi-year global satellite data sets. It will be tested during process studies such as the GEWEX Continental-Scale International Project (GCIP).

An integral part of NOAA's data system modernization will be participation in the U.S. Global Change Research Program and its information management system, the Global Change Data and Information System (GCDIS). NOAA is a major participant in providing an interagency gateway for access and delivery of data and information products; NOAA also develops numerous products describing the state of the environment to users requiring processed information to apply to everyday problems of business, industry, and commerce. NOAA has partnerships with the National Aeronautics and Space Administration on the EOSDIS, with eight other agencies in GCDIS, with the National Science Foundation for MOSAIC, most agencies for FGDC, in the Department of Energy National Storage Laboratory, and academia.

To support research on furthering our understanding of seasonal to interannual climate variability, NOAA will provide for new modern research vessels to carry out at-sea monitoring and oceanographic research projects. Collection of ocean observations from the equatorial Pacific on a routine basis, as well as research data from other ocean basins, is critical to the ability to model and forecast climatic events. As part of the NOAA Fleet Replacement and Modernization (FRAM) Program, two new vessels -- the KA'IMIMOANA and the RONALD H BROWN -- will be delivered in 1996 and 1997 respectively. The KA'IMIMOANA will provide dedicated support for maintaining the Pacific TOGA-TAO array, and conducting oceanographic research. The AGOR-24 class, RONALD H BROWN will support general purpose oceanographic research cruises. In addition, UNOLS, academic research vessels, and contracts will be employed to help meet NOAA's goal.

Objective 3. ***Conduct research for improved climate predictions***

NOAA's research program to understand seasonal to interannual climate variability and its predictability includes studies on the evolution of SST anomalies as part of the oceanic response to atmospheric forcing, observing and understanding annual and interannual variations in the tropical Pacific, and meteorological studies on regional and large-scale sea-air interactions and the global Southern Oscillation signal. NOAA also has major ongoing efforts in modeling, which unify atmospheric and oceanographic research, including ongoing programs to develop operational ocean general circulation models (GCM) and assimilation systems capable of realistically "nowcasting" tropical ocean circulation, temperature, and salinity fields. Atmospheric GCMs are being developed in order to

examine the effects of SST anomalies on the atmosphere, with special attention being paid to the climate over North America. Coupled atmosphere-ocean climate models have been developed and are the basis for much of the optimism for ENSO prediction. In an experimental mode, the models have been able to simulate and forecast features of ENSO influences over the United States.

Part of NOAA's research support for seasonal to interannual climate forecasts involves an international research effort for climate prediction. This concept includes research, modeling, and experimental predictions of interannual climate variations, training of scientists in the utilization and interpretation of the predictive models, and development and delivery of products useful to decision-makers in participating countries. In addition, NOAA has the lead for the U.S. development of GOOS, the activity to obtain the operational ocean measurements required for seasonal to interannual predictions, for improved marine weather and ocean services, for detection of long-term changes in the ocean and its ecosystems, and for provision of information to coastal zone managers and users.

TOGA, while successfully demonstrating the predictability of aspects of seasonal to interannual climate variations, has much to be accomplished. TOGA concentrated on ENSO in the Pacific to the exclusion of other interannual signals in other tropical oceans and at higher latitudes. The connection of the tropical to mid-latitude variability, the effects of land surface processes, and the impact to predictability of coupled interactions in the Atlantic and Indian Oceans need to be investigated. Furthermore, the nature of the mid-latitude variability needs to examined. Recent studies are suggestive of coupled air-sea interactions on the intradecadal time scale in the North Pacific, which have strong impacts on climatic variability over North America. The latter investigations will be carried out jointly with the Predict and Assess Decadal to Centennial Change goal of this Plan.

NOAA will invest in the following research programs that directly address issues that will extend the predictability of ENSO and the accompanying meteorological effects, and explore interannual predictability originating from other sources: the Global Ocean Atmosphere Land System (GOALS) Program, a 15-year follow-on program begun in 1995; and the GEWEX, the key international program to improve the parameterization of water and energy fluxes in coupled air-ocean-land models.

- GOALS: The GOALS program has been formulated to continue improvements in prediction of ENSO, extend our understanding and predictive capability to include global seasonal to interannual climate variations, and develop the observational and computational means for predicting these variations. The central hypothesis of GOALS is that the variations in the global boundary forcing of SST, soil moisture, sea ice, and snow exert a significant influence on seasonal to interannual variability and potentially enhance predictability. Both understanding variability and predicting climate require GOALS to provide accurate measurements of global boundary conditions and improved measurements and models to simulate their future evolution.

Research in GOALS will continue to emphasize the ENSO region with the ongoing support of ENSO modeling and data analysis. GOALS will, however, move beyond the tropical Pacific and extend investigations into the roles of other tropical oceans, higher latitude oceans, and land surface processes in determining seasonal to interannual variability. The first such extension will be the Pan American Climate Studies Program, designed to improve seasonal climate predictions over the Americas and contiguous waters, emphasizing monsoon and summertime precipitation. GOALS will further investigate the seasonal to interannual variability and predictability of climate in other regions of the globe, including Africa and the Australasian monsoon system.

- GEWEX: The GEWEX program focuses on the characteristics of the global hydrological cycle and related energy fluxes. Climate prediction requires knowledge of these fluxes and, in particular, needs parameterizations of physical land surface processes for use in predictive models. GEWEX will provide such parameterizations to GOALS. The implementation of the GCIP is the most important activity for NOAA's GEWEX program during the next five years. GCIP is being conducted in the Mississippi River basin to determine the significance of the many land-atmosphere interactions and land surface processes to climate variability and prediction. The Mississippi basin provides the world's most comprehensive suite of data systems for evaluating the hydrological cycle and energy exchange budge on a continental scale. The results from GCIP will result in improved predictions of droughts and floods in this region.

- Modeling Research: Skillful prediction of climate anomalies will require improved coupled ocean-atmosphere-land surface models and the means for initializing the forecasts. A hierarchy of coupled models with a wide range of complexity needs to be employed in simulation and prediction studies to increase our understanding and improve predictability. Sophisticated data assimilation techniques need to be developed for the coupled system in order to gain optimal use of the observing system for climate diagnostics and initialization of coupled forecasts.

  Although prediction of tropical Pacific sea surface temperature is not simple, the task of predicting the related atmospheric climate anomaly patterns is yet more difficult. The atmospheric general circulation model used for this must be of the highest quality possible. Further work needs to be done to improve the parameterizations of convection, cloud formation, and perhaps other physical processes since recent research has shown that the model response to SST anomalies is very sensitive to cloud properties.

  Statistical techniques have been used to develop a basic understanding of the atmospheric response to SST anomalies. However, the atmospheric general circulation model is a more sophisticated tool that can refine our knowledge substantially. To this

end, a large number of simulations of the recent past need to be run using observed SSTs to determine the magnitude and reliability of the climate anomalies, for a given model and for nature. Since predicted SSTs will inevitably have some error in them, similar studies using them are also needed. These studies are central to determining the reliability of predictions of mid-latitude climate anomalies.

Ecosystem Response to ENSO: Much of our understanding of the response of marine ecosystems to ENSO events is either anecdotal or so qualitative that little predictive capability exists in this area. Nevertheless, fisheries and other living marine resources are especially vulnerable to over-exploitation and collapse during warm ENSO events; the effects of ENSO events are reflected in reduced landings and consequent reduced total value of catch. A key goal of the U.S. Global Ecosystem Dynamics (GLOBEC) program is to provide quantitative information to managers and policymakers on the impact of ENSO on living marine resources in the Subarctic Pacific and California Current. Detailed economic analyses of the impacts of ENSO on fisheries and the social value of predictions are also planned.

To test various scenarios and produce assessments of ENSO impacts, the U.S. GLOBEC research plans include construction of coupled physical-biological models at the local and regional scale that simulate ENSO forcing and biological response; study of cause-effect relations between ocean physics and ecosystem response through retrospective analysis of existing time series and through process research; and long-term monitoring of the physics and biology of the California Current to study impacts of future ENSOs on living marine resources and to monitor the recovery of selected populations following ENSO events. The fisheries prediction studies that incorporate environmental variability related to ENSO into their models will be performed in the Build Sustainable Fisheries goal of this Plan. This goal will work with them on documenting, modeling, and predicting the changes to the physical environment related to ENSO.

Objective 4. ***Deliver climate services and assess socioeconomic impacts***

The goal of this objective is the regular and dependable delivery of climate services, defined as providing climate predictions, products, and information to users for applications that guide sustainable development, reduce commercial risk, and achieve social benefits. In addition, an organized program of research on the socioeconomic impacts and vulnerabilities and assessments to provide policy-relevant information will maximize economic and social benefits.

NOAA is actively engaged both nationally and internationally in ensuring that climate predictions and products will be used to reduce the risks to health and wealth. Nationally it proposes to enhance its capability to provide climate services. This effort will begin with workshops to inform users in the private, state, local government, and Federal sectors of

forecast products and procedures; and to assess their needs. The effort will evolve towards a network of cooperative institutes between NOAA and appropriate academic institutions, who will work in partnership with the private sector, to provide products and services to enhance regional economic capabilities.

Products and services of two kinds will be provided: those with a direct and immediate economic benefit to customers and those whose benefit is more diffuse. The first type will require a partnership with the private sector. The second type, where the technical development has not reached the stage where profitable delivery is possible or in which the benefit is broadly applicable but too small to motivate individual customers to pay, are good candidates for collaboration with the academic community.

Since impacts resulting from climate variability depend in large part on the specific regional social and economic context, studies need to assess the regional impacts of climate on key economic sectors and resource management decisions. Interdisciplinary approaches linking analyses of physical, biological, and social systems in regions particularly vulnerable to climate variability will be developed. Some of the regional assessments envisioned include the Great Lakes basin, U.S. Pacific northwest region, and southeastern U.S.

Internationally, NOAA is aiding in the development of applications with a proposal to launch an SCPP. Central to the SCPP proposal are Regional Application Centers established and funded by participating countries to generate products of immediate social and economic value. In addition to the economically important sectors already mentioned, application experience will make an essential contribution to efforts to address such pressing environmental issues as desertification, wetland deterioration, preservation of biological diversity, and systematic food productions matters. SCPP Application Centers are designed to ensure that the users play a role in defining the product. Forecasts will be tailored by the Application Centers employing the advice and needs articulated by local decision-makers to provide products that will be effective, understandable, and useful in formulating policies, laws, strategies, and incentives.

Many developing countries are most directly affected by ENSO events; their economies are dependent upon their agricultural sectors as a major source of food supply, employment, and foreign exchange, which is key to economic growth and continued participation in world markets. In these countries, drought predicted up to several months in advance, coupled with response options effectively communicated to local farmers, has already contributed to maintenance of employment and food supply, allowing the government to save scarce financial resources and the communities affected to avoid unnecessary suffering. Enhanced capability on the part of these governments to address disasters and economic bottlenecks can result in reduced demand for emergency aid from the U.S.

- Economic and Human Dimensions Analyses: Natural climate variations are among the key environmental factors influencing changes in disease vectors and microbiological

agents. In particular, early research efforts indicate that El Niño anomalies can lead to conditions that generate new breeding sites for disease vectors and bursts in their abundance. The advent of climate forecasts available a year or so in advance has the potential to offer public officials the information and lead time necessary to undertake preventive actions.

The pervasiveness of economic and other human consequences of ENSO events reflects the importance of forecasting capabilities for economic growth and competitiveness, public health, and the efficient management of natural resources. Analyses must be conducted to further articulate the effects of ENSO events on various U.S. commercial sectors, human inputs and adaptations to climate, and potential benefits from various levels of improvement in predictive accuracy. It is important to identify the spatial and temporal time frames of the ENSO products that will be of most benefit to the various affected sectors of the economy. Research on the value of improved forecast information provides methodologies that may be applicable to economically productive sectors and regions.

The global nature of climate variability mandates ongoing bilateral and multilateral cooperation. Multinational cooperation, which provides for leveraging of financial and scientific resources, increases our knowledge and facilitates our predictive capabilities, including forecasts of the socioeconomic dimensions of change. Governmental and private funding agencies, such as the Global Environmental Facility, will more readily make long-term resource commitments to these programs once socioeconomic impacts are better quantified.

- Development of a National Climate Variability Education Plan: A major focus of climate research is the development of an informed and responsible citizenry, knowledgeable about climate variability. A program in public education will incorporate trained outreach specialists in climate and global change, an advisory panel to private industry, creation of public information literature, displays and exhibits, and public service announcements on broadcast media. Longer time-scale actions include the development of curricula for use in primary and secondary education programs, the establishment of fellowship programs for educators, and post-doctoral programs. These programs will provide decision-makers and the public with the foundation and information needed to support policy decisions and actions.

CONCLUSION

Research efforts have shown that we can now predict El Niño events to a level of skill and with enough lead time that potentially hundreds of millions of dollars a year could be saved in the United States and abroad. To do this on a continuing basis, we need to institutionalize systems for making routine forecasts and delivering climate services, make operational the observing system required for the predictions, and support the basic research required to

improve the predictions. NOAA will provide this function for the U.S. and will contribute to a multinational effort to gather, produce, and disseminate climate information worldwide. The cost is a small fraction of the economic return to the Nation.

PREDICT AND ASSESS DECADAL TO CENTENNIAL CHANGE

VISION

NOAA will provide science-based options for decisions regarding decadal to centennial changes in the global environment, specifically for: climate change and greenhouse warming, ozone layer depletion, and air quality improvement.

THE CHALLENGE

The Earth's climate system has shown substantial natural variation in the past, often with severe impacts on humankind. The recent Sahel drought and the Midwestern U.S. Dust Bowl of the 1930's are examples of decadal climate changes. The Little Ice Age of 1400-1800 exemplifies high-impact climatic fluctuations over several centuries. Undoubtedly, such natural climatic swings will be a part of our future.

Human activities are inducing additional changes, with potential impacts of comparable magnitude. These changes, observed on decadal time scales, are evident now. Atmospheric pollution hangs over many regions of the Northern Hemisphere. The thinning of the stratospheric ozone layer, most notably over Antarctica, is expected to persist for nearly another century. Greenhouse gases being added to the atmosphere will reside there for decades to centuries and are predicted to increase average global surface temperatures by several degrees Celsius, a change larger than the natural variation over the past 15,000 years.

The challenge is to forecast high-impact decadal-and-longer changes with predictions of sufficient scientific credibility to support action. Such changes have enormous impacts on societies and governments and pose critical prediction and assessment needs for a world of increasing population, food requirements, and societal stresses. Foreseeing the natural environmental variations of the approaching few decades is to be able to adapt our industry, trade, and lifestyles to a future environment that we cannot influence. Foreseeing the perturbations that we are causing to the environment will enable us to make sound choices as to how we can live in better harmony with the environment. This is equally true for decisions that avoid future changes (e.g., global warming) and decisions that repair current situations (e.g., regional air quality). The framework for these policy choices already exists in the United Nations Montreal Protocol, the Framework Convention on Climate Change, and the U.S. Clean Air Act.

Decadal-and-longer changes place a special credibility requirement on predictions and associated assessments. In contrast to the credibility of tomorrow's weather forecast which is tested quickly, the predictions of changes decades ahead are input to decisions faced long before the predicted change can be observed. This need is particularly acute for environmental changes that either cannot be reversed rapidly (e.g., global warming from

long-lived greenhouse gases) or that can occur quickly (e.g., those climatic changes seen in the paleoclimatic record in periods not too different from today). The keys to such credibility lie in the completeness and rigor of the research and its results. Therefore, a prime need facing our Nation and the governments of the world is to predict the possible natural and human-induced environmental changes of the coming decades and to predict how best to repair the problems at hand. The separation of the natural variability from human-induced changes is one of the most significant aspects of this research. Only then can public policy, private-sector economic strategies, and other societal decisions be made effectively over the next several years. NOAA's predictions and assessments will be contributed to the Intergovernmental Panel on Climate Change (IPCC) for climate issues and the UNEP/WMO Ozone Assessments for stratospheric ozone issues.

Although once considered as separate environmental issues, it is increasingly being recognized that the phenomena of greenhouse warming, ozone-layer depletion, and regional air pollution are all inter-related. As research seeks to better understand these couplings, the scientific assessments associated with these issues must also provide decision makers a more integrated statement of the current understanding that can aid the formulation of broader-scoped, and hence more effective, policies.

SUMMARY OF OBJECTIVES

This program addresses the environmental policy needs that currently face or soon will face the Administration and world governments. The climate change components are to be submitted under the Climate and Global Change Program as a contribution to the U.S. Global Change Research Program (USGCRP) and are subject to review by the Committee on Environment and Natural Resources (CENR). The "Repairing Our Air Quality" component pertains to important regional long-term changes and is reviewed by the Air Quality Subcommittee of the CENR. The major objectives are to:

Objective 1. ***Characterize the forcing agents of climate change***

NOAA will focus on the agents and processes that force climate change on decadal to centennial time scales. This includes (1) characterizing the greenhouse gases involved in near-term policy decisions, (2) determining the role of aerosols and ozone depletion in altering the radiative forcing of the climate system, (3) examining solar variability as a factor in climate change, and (4) investigating the paleoclimatic record for periods of substantial changes.

Objective 2. ***Understand the role of the oceans in global change***

The potential for the ocean in redistributing heat on the planet is a major source of uncertainty in modern climate models. NOAA is examining the role of the global ocean as a major reservoir of both heat and carbon dioxide (CO_2). The ocean's ability to take up

carbon dioxide remains a poorly quantified term in the global carbon budget. Continuing programs of basin-scale research are identifying the critical processes controlling air-sea fluxes of these parameters. Long-term observations of the ocean will improve our understanding of these processes and provide the baseline environmental descriptions needed for detection of climate change. NOAA is leading the national planning and implementation efforts for the U.S. contributions to the international Global Climate Observing System (GCOS) to provide necessary observations as part of the Global Ocean Observing System.

Objective 3. ***Ensure a long-term climate record***

Enhance existing operational weather networks, observing procedures, and information management systems to fulfill requirements for long-term climate monitoring. NOAA's present in situ and space-based observation capability is designed for weather prediction and assessment, not long-term climate monitoring. As a consequence, many critical climate variables are measured and archived inadequately. Data quality and continuity have been compromised. As a result, the science of global climate change is being thwarted by uncertain information about critical climate trends, a central concern of GCOS.

Objective 4. ***Guide the rehabilitation of the ozone layer***

NOAA will provide the scientific basis for policy choices associated with chlorofluorocarbon (CFC) and halon substitutes and provide better characterization of other ozone-depleting compounds such as methyl bromide. Choices on replacements for substances that have many industrial applications will have large impacts on the economy. Lastly, documenting the recovery of the ozone layer in the next century will increase public confidence in the effectiveness of environmental actions.

Objective 5. ***Provide the scientific basis for improved air quality***

NOAA will focus on regional environmental changes addressed by the Clean Air Act Amendments of 1990. This research will enable us to: (1) develop an understanding of high surface ozone episodes in rural areas, where crop and forest damage is a growing environmental concern, which are not addressed explicitly by current regulations, and (2) establish a monitoring network in the United States that will provide early detection of the cleaner air quality so that the subsequent, more-difficult emission reductions can be done more effectively because of a sounder scientific basis.

Objective 6. ***Provide prediction, assessment, and human impact information***

NOAA will develop advanced models for the prediction of long-term natural and anthropogenic climate change, lead and carry out state-of-understanding scientific assessments, and provide the linkages to the impact and assessment communities. For example, the study of the human dimensions of global change require better information on

model strengths and limitations in order to assess greenhouse gas policy options. The same is true regarding regional implementation of the Clean Air Act. NOAA also has a key role in determining the response of marine ecosystems to climate change and in linking social and economic aspects of climate change to ecosystem structure and to the abundance of living marine resources.

BENEFITS

SUPPORT OF NATIONAL GOALS

- Assist with the Administration's environmental goals: The President committed the Nation to stabilizing its emissions of greenhouse gases by the end of the decade. The cost-effective implementation of that commitment requires decisions that are based on a sound understanding of the global-warming problem (e.g., short-lived vis-a-vis longer-lived greenhouse gases) and its relation to natural changes (e.g., the background of large-scale natural climate change). Furthermore, implementation of the Clean Air Act Amendments of 1990 will need to incorporate the most up-to-date air-quality science to enhance the environmental payoff from the substantial expenses to be involved. Lastly, the United States is a party to international commitments to eliminate the production of the major ozone-depleting compounds within a few years, and science is being turned to for advice on "ozone-friendly" substitutes and further means for rehabilitating the ozone layer.

- Assist with the DOC goal of achieving sound environmental assessment, prediction, and stewardship: A sound assessment of the current state of scientific understanding of environmental issues is the fulcrum that yields the effective balance in decisions regarding environmental protection and a healthy economy. At the heart of these scientific assessments lie predictions whose credibility rests upon careful observations and insightful characterizations of key Earth-system processes. Formulating and carrying out research, helping to embody the results in up-to-date assessments, and describing the implications in policy-relevant terms to government and industrial leaders are the cornerstones of environmental stewardship.

BENEFITS TO THE NATION

Research that addresses the needs of key current and emerging environmental issues should produce substantial and immediate results. A major benefit of this program continues to be key scientific input supplied to the United Nations scientific assessments (e.g., the Intergovernmental Panel on Climate Change [IPCC]) that will guide the Montreal Protocol on Ozone and the Climate Convention (or its Protocol) on greenhouse warming. These policy-relevant assessments will provide the basis for highly visible decisions by governments and industry. Climate process and modeling studies will provide our best estimates of the climate consequences of greenhouse gas emissions. The trace-gas data will help establish priorities

for the greenhouse gases that deserve the most focus. The aerosol information will provide input to more-complete global warming predictions. Examples of other benefits include:

- A clearer picture of the roles of various greenhouse and ozone-depleting gases in causing global warming. Since President Bush committed to addressing all greenhouse gases, this quantitative information and better predictions of climate response to emission changes will aid the cost-effective choices to protect the climate system from anthropogenic effects. The initial policy decisions regarding a Greenhouse Gas Protocol that is a likely follow-on to the Framework Convention on Climate Change will have to be based on the confidence in climate model predictions, since unequivocal observations of a greenhouse warming are not likely by that time.

- Narrowing of uncertainties in the global carbon dioxide budget. Our present uncertainty in the global budget of sources versus sinks of carbon is about 1.8 gigatons, as compared to the total U.S. emissions of 1.3 gigatons. A major improvement in our estimates of these processes will be invaluable in future global negotiations on reducing carbon dioxide and other greenhouse gases. The value of reducing climate-related uncertainty in the implementation of policies on stabilizing anthropogenic greenhouse gas emissions is estimated to be $100 billion for the U.S. alone between now and the year 2020[15].

- Support for a range of industries influenced by climate variability. The insurance industry alone has hundreds of billions of dollars at stake and is at risk due to inadequate data bases regarding the frequency and magnitude of major climate events. Utilities have concerns over long-term cooling and heating requirements. When the NOAA 100-year coupled model run was first made accessible this year, 15% of the users of these data were industries.

- Early detection of climate change. One of the most critical components of implementing and sustaining a policy on anthropogenic greenhouse gas emissions relates to demonstrable impacts on the climate. With modest improvements to our existing weather watch networks, we can assure that real climate signals will be identified at the earliest possible date.

- Aiding rehabilitation of the ozone layer through a better definition of the choices facing a U.S. Government committed to aggressive protection of the ozone layer. A key issue is determining which substitutes for the soon-to-be-banned CFCs will be the most "ozone friendly." The cost of setting up an industrial plant for the production of a substitute exceeds $25 million; such information will help our industry to avoid retooling factories for a substitute that later proves to destroy unacceptable amounts of

[15] Manne, A. and R. Richels, *Buying Greenhouse Gas Insurance: The Economic Costs of Carbon Dioxide Emission Limits*, Chapter 4, Decision Making Under Uncertainty (MIT Press, 1992).

ozone, and will help our Nation's international competitiveness by ensuring early commercial availability of acceptable substitutes.

- Supporting air quality improvement through scientific assessments for the Congress on: (1) the causes of rural ozone and predictions of options for implementing the Clean Air Act Amendments (CAAA) so as to help reduce both urban and rural ozone, (2) improved predictions of the most effective way to perform the Phase II reductions scheduled around the year 2000, (3) the costs and benefits of the acid deposition control program created by Title IV of the CAAA, and (4) the reduction in deposition rates that must be achieved in order to prevent adverse ecological effects. The assessments will clarify which Clean Air Act decisions could help with urban ozone, rural ozone, and acid deposition. The payoffs are substantial. The former Office of Technology Assessment stated that reductions of 25% in rural ozone levels could boost U.S. crop yield by $1 billion per year. The Environmental Protection Agency estimates that the Phase II reductions will cost over $10 billion per year, clearly implying that improved knowledge (such as effective state-by-state implementation, in contrast to a blanket U.S. policy) provides a high value in cost savings.

- Observations of the improvements in national air quality as soon as possible after the first emission reductions become law. These data will substantially define the details of the need for and implementation of subsequent emission reductions and demonstrate to the public what they are getting for their increased expenditures, thereby increasing public support for environmental legislation.

THE STRATEGY

RELATIONSHIP TO NOAA MISSION

These research programs are linked directly to the environmental prediction and assessment mission of NOAA to carry out cutting-edge research for scientific input to sound policy formulation and to describe the results in policy-relevant terms. The proposed activities are an extension of NOAA's charter to predict to decadal and centennial time scales. NOAA's strength rests on four foundations:

- NOAA is a recognized major source of research and information on national and international environmental issues. NOAA and NOAA-supported academic colleagues have made the scientific discoveries that drive many of the environmental policy decisions being debated today. For example, NOAA is a major contributor of research results to the IPCC and Montreal Protocol Science Assessments (on stratospheric ozone), which have figured prominently in governmental policy formation such as the national and international policy of ozone-depleting substances. NOAA's scientific findings in policy-relevant terms (assessments) have helped governments and industries with policy decisions. The NOAA scientists and research managers who have made

these discoveries and subsequent science assessments are best positioned to pursue their implications in the most cost-effective way.

- NOAA has an acknowledged Federal role under the USGCRP; NOAA is responsible for in situ and satellite observation and monitoring programs; mission-directed research on physical and biogeochemical processes in the climate system; development, testing and application of models, and maintenance and distribution of long-term data bases of climate information. Its role in the long-term prediction of changes in the atmosphere derives naturally from its historical responsibilities in weather prediction, focused climate and ozone-layer research, advanced modeling, and data management. NOAA also is required by the Clean Air Act to provide scientific assessments relating to stratospheric ozone depletion.

- NOAA is a leader in established coordinating mechanisms. NOAA plays a leadership role in the CENR, which submits coordinated, prioritized budgets for Federal research programs to the Office of Management and Budget after approval by the respective agencies and review through the CENR. NOAA serves as Vice-Chair of the CENR Subcommittee on Air Quality Research. The National Acid Precipitation Assessment Program is another coordinating mechanism; NOAA is one of six member agencies and hosts the Office of Director. International coordination is as important to global research programs as national coordination. NOAA scientists helped establish many of the activities of the World Climate Research Programme and the International Geosphere/Biosphere Programme.

- NOAA's vision is to balance economic and environmental issues. The effort to certify CFC replacement compounds is a case study in minimizing economic impact of an action to protect the global environment, i.e., a way to have an ozone layer and refrigeration. This is an integral part of predicting global environmental changes and their effects on the environment, resources, and human society.

OBJECTIVES

Building upon its strengths in climate research, NOAA will address the societal questions that the U.S. and the world face in air quality, ozone depletion, greenhouse warming, and climate change. NOAA's goal is to provide the science needed for imminent policy decisions and to provide information on emerging scientific issues that have high policy relevance.

Objective 1. *Characterize the forcing agents of climate change*

NOAA's research program to characterize forcing agents of climate change has focussed on natural agents such as volcanic aerosols and solar variation as well as human-related inputs. This program is gaining a predictive understanding of decadal to centennial changes. In particular, NOAA is studying the atmospheric chemical and transport processes that

determine the atmospheric residence times of greenhouse gases, a major factor in their effectiveness in the radiative forcing of climate change. Field studies provide a characterization of these processes, such as global transport patterns, the abundance of naturally occurring chemicals that remove gases from the atmosphere, and temporary chemical reservoirs that can delay that removal. Laboratory investigations yield quantitative data that allow models to numerically incorporate these processes in their predictions. Similar information is being provided for processes that control stratospheric ozone depletion: reactions that occur on the surfaces of particles and those that remove the substitutes for ozone-depleting compounds in the lower atmosphere, thereby protecting the stratospheric ozone layer.

NOAA is monitoring a number of climate forcing agents, including the hallmark 30-year CO_2 record from NOAA's Mauna Loa Observatory and NOAA records of methane abundances globally. Laboratory, field, and modeling studies complement this monitoring activity. For example, NOAA has found that methane is removed from the atmosphere more slowly than was originally thought, which implies a larger greenhouse role for this gas and has heightened the focus on ways to lower its emissions. NOAA also discovered that CFCs, in addition to their direct greenhouse role, have a cooling role that tends to offset some of the warming. This finding has slightly lowered the global warming predictions. Solar variability is also an important issue in climate. As recommended by the National Academy of Science report on Solar Influences on Global Change, NOAA is monitoring total solar irradiance, and will soon be monitoring solar imagery, and energetic particles in the vicinity of Earth.

NOAA studies of aerosols address the IPCC's increasing focus on aerosols: whether human activities on aerosol emissions; predictive models that include radiative and microphysical processes; general circulation models that incorporate cloud/aerosol/radiation physics; and the role of tropospheric aerosols in radiative forcing of climate.

Because the economic stakes associated with decisions on greenhouse gasses are high, knowledge regarding the greenhouse roles of many gases is of premium value. Additional efforts are necessary to understand the roles of CO_2, methane, and other gasses as well as to understand the natural variability of climate. Future efforts include:

- Monitor trends of atmospheric greenhouse gases, including water vapor; emphasize understanding their interaction. An understanding of the recent unexpected decline in the growth of CO_2, methane, and nitrous oxide is critical to predicting greenhouse warming under future emission scenarios. Studies of methane distribution and loss rates are important since methane emissions may have a stronger impact on warming than anthropogenic CO_2.

- Perform laboratory, process and modeling studies of the global warming potentials (GWP) of gases that are candidates for emission reductions, including methane,

perfluorocarbons (proposed substitutes for ozone-depleting gases), nitrogen oxides, and carbon monoxide. The latter two contribute to the formation of ozone, also a greenhouse gas.

- Improve observations and three-dimensional models of atmospheric processes to study the impact of short-lived emissions such as plumes of nitric oxides and aerosols from airplanes.

- Determine the role of pollution-produced aerosols in climate. Monitoring sites will establish the abundance and trends of Northern Hemisphere aerosols; field and laboratory studies will characterize their climate-related physical/chemical properties. Climate models will then be used to estimate the cooling role of these aerosols and how cooling by aerosols influences greenhouse gas-induced warming.

- Synthesize data from the observed modern record with the paleoclimate record to document past changes in climate. Enhance spatial coverage of paleoclimate records in poorly sampled regions, and use the paleoclimate record in coral reefs to discern the natural response of marine ecosystems to long-term climate variability.

Objective 2. ***Understand the role of the oceans in global change***

The oceans play a role in both seasonal to interannual and decadal to centennial climate variability; deep-ocean processes are primarily significant on longer time scales. Numerical models show a central role for the deep thermohaline circulation of the Atlantic Ocean, or "conveyor belt," in the evolution of natural decadal to centennial climate variability, and in the planet's response to greenhouse forcing. Current NOAA research on the role of the ocean in determining long-term climate is designed to collect and analyze oceanographic data to evaluate predictive models for long-term climate change; to define the climatically important decadal time-scale ocean features in the Pacific, Atlantic and Indian Oceans; and to understand interactions between circulation, sea surface temperature, salinity and global climate in the Atlantic Ocean. To do this, observations on anthropogenic tracers in the ocean and hydrographic data are collected across ocean basins on a regular basis. Observations of the tropical Atlantic are being used to determine mechanisms for cross-equatorial and cross-gyre exchanges in order to develop observational strategies to document secular changes in water mass properties. Paleoclimate records strongly suggest a relationship between Atlantic circulation and climate on long time scales.

The oceans are a major reservoir for CO_2 and a major participant in the cycling of CO_2. Studies of the global carbon cycle provide an improved understanding and assessment of global atmospheric CO_2 budget, including determining the role of the oceans and land biosphere in modulating the atmospheric carbon dioxide increase. Ongoing efforts include examination of the large-scale concentration patterns of CO_2 through carbon system measurements on deep ocean survey cruises; time-series measurements of atmospheric $^{12}CO_2$

and $^{13}CO_2$ through the global cooperative flask sampling network; and carbon system modeling using ocean and atmosphere general circulation models. Tower-based studies are also examining how the terrestrial biosphere absorbs carbon dioxide, which could be a major factor in understanding the cause of the imbalance in the global carbon budget.

The chemical and thermal state of the ocean is also influenced by seafloor hydrothermal activity and venting, through supply and recycling of heat and chemicals. These processes in turn affect deep ocean circulation. Ongoing research and technology development are focussed on quantifying these processes and on determining the magnitude and variability of these volcanic and hydrothermal processes on decadal to centennial time scales.

Further efforts to study the role of oceans in climate variability will:

- Expand ocean-atmosphere field studies in the North Atlantic. Historical data studies suggest that the Newfoundland/Labrador Sea region is an area of intense air-sea interaction associated with long-term changes in the North Atlantic climate. A combined circulation and air-sea exchange study, the Atlantic Circulation and Climate Experiment, is being planned and is a strong candidate for interagency support.

- Enhance studies of oceanic uptake of carbon dioxide. Repeated ocean transects of carbon system parameters and tracers will lead toward a better quantification of the oceanic uptake of CO_2.

- Support long-term ocean time series. Through this Plan, the Global Ocean Observing System will support these time series on a continuing basis. The time series (e.g., global sea level coastal temperature and salinity stations) are the benchmark for judging future changes in the oceanic and coastal environment.

NOAA will have modern research vessels available to help support monitoring, data collection, and research aimed at understanding decadal to centennial changes in the global environment. Oceanographic data, collected by ships at sea, is one of the important elements in developing and refining global models of the earth's environment and its reaction to natural and human-induced change. The new AGOR-24 class, NOAA vessel -- RONALD H BROWN -- to be delivered in 1997, will provide a modern research platform for carrying out long-term investigations into the role of the oceans as a reservoir of both heat and carbon dioxide, and it's contribution to climatic change. In addition, UNOLS and academic research vessels will be employed to help meet NOAA's goal.

Objective 3. ***Ensure a long-term climate record***

NOAA is collecting a long-term record of climate information in order to detect changes, to verify models, and to understand the sensitivity of climate to natural and man-made influences. This information also supports studies of the impact of climate variations on

social, economic, biogeochemical, and physical systems. NOAA's archives of earth system observations, including both satellite and ground-based observations, represent a wealth of raw material for developing long-term climate records. NOAA has developed several quality, long-term data sets, e.g., the Comprehensive Ocean Atmosphere Data Set (COADS) and NOAA/NASA Pathfinder which are continually maintained and are being used to study long-term climate variability.

NOAA can capitalize on its investment and infrastructure in weather monitoring and operational satellites to begin to address the long-term climate monitoring problem. Few long-time series exist in the ocean; some of them have traditionally been supported by research funds and are in danger of being ended. NOAA is assuming the support and enhancement of some of these time series because they are critical benchmark against which to judge future changes in the oceanic and coastal environment. The longest time series is the global ocean sea level stations, which is moving from a research to an operational program.

Global views of sea surface temperatures are provided by satellites but require continuous and widespread validation by in situ measurements from buoys and ships, programs supported and conducted by NOAA. The NOAA Polar-orbiting Operational Environmental Satellites (POES) and Geostationary Operational Environmental Satellites (GOES), designed primarily to support NOAA's short-term warning and prediction mission, are providing the global coverage and continuous observations that are valuable in monitoring and documenting decadal to centennial variations. Satellite records up to two decades long are now used to analyze variations in global tropospheric and stratospheric temperature, snow cover, sea ice, cloudiness and vegetation. The POES also carries the Solar Backscatter Ultra-Violet/2 radiometer for monitoring long-term trends of atmospheric ozone.

The long-term paleoclimate record is essential to assembling a long-term climate record, and for determining the natural variability of the climate system. NOAA is beginning to organize and understand the large volumes of proxy records available.

A number of specific actions are required to ensure adequate long-term climate data. It is essential to assess the effects on long-term climate monitoring of both planned significant changes to existing systems and new operational observing systems. Assessing all systems on a routine basis will ensure the relevance of existing observing systems to long-term environmental monitoring, including climate. Further efforts relate to both in situ and satellite measurements:

In Situ Measurements:

- Modernize the cooperative weather observing network. Replace 19th century technology with modern instruments and communication systems in such as way as to ensure a seamless transition from old to new technology. As part of this effort,

establish a climate reference network from the existing set of the longest, most complete, and highest quality long-term cooperative weather stations.

- Augment the National Weather Service modernization efforts by upgrading the new Automated Surface Observing System (ASOS) stations for climate observations. Improvements needed include redesigning precipitation gauges, improving accuracy of temperature monitoring, and a way to measure clouds above 12,000 feet that is consistent with past measurements.

- Enhance the upper air system. Develop a reference radiosonde for comparison with existing sounds being used in support of daily weather forecasts. Provide support for adequate metadata associated with instrument characteristics. Archive data as close to the original engineering units as possible so that errors in processing can be rectified as they arise.

- Routinely assess the homogeneity of observing system data to guard against spurious trends in the data (e.g., provide sufficient overlap between new and old tide gauge instruments to preserve the homogeneity of the sea-level records). Also, support the interpretation of climate trends by improving the continuity and quality of the information (metadata) about observing procedures and the instruments used to measure climate quantities.

Satellite Measurements:

- Upgrade existing satellite sensors for climate observations. Needed improvements include installation of station-keeping propulsion systems on satellites to maintain a constant observing time, installation of on-board calibration devices for solar reflectance channels, and overlapping successive satellites period of one year to intercalibrate instruments.

- Consider operational satellite measurements of solar irradiance, Earth radiation budget, and aerosols. Sensors to measure these critical climate forcing variables have been demonstrated in a research mode but have not been implemented on the geostationary or polar orbiters.

- Improve the continuity and quality of metadata, information about the observing procedures and instruments used to measure climate quantities. Develop NOAA's capability to communicate and archive critical information about instrument type, manufacture, calibration procedures, observing schedules, locations, etc., which affect the interpretation of climate trends.

- Building on the NOAA/NASA Pathfinder system, develop the capability to process, analyze, assess, and disseminate data and information on decadal change based on

NOAA's vast holdings of raw satellite and ground-based observations of the climate system.

Objective 4. ***Rehabilitate the ozone layer***

NOAA researchers have led the world in discoveries that have dramatically changed our understanding of human influences on the ozone layer. These activities include ground-based monitoring of ozone trends and of gases that cause those trends, discovering the cause of the Antarctic ozone "hole," coordinating world scientific assessments of the state of understanding, and conveying the significance to policymakers. To ensure that near-term decisions regarding ozone-layer protection and economic health are made from a sound scientific base, newly recognized ozone depleters, such as methyl bromide, must be better understood. Future efforts will:

- Develop and deploy new instrumentation essential for enhanced observation, analysis, and understanding of the role of ozone depleting chemicals. The peak of stratospheric ozone depletion rates is anticipated to occur over the next decade; this instrumentation will also allow observation and verification of the recovery of the ozone layer that is predicted to occur over several decades as inputs of chlorine and bromine (and thus their stratospheric levels) decline.

- Enhance the capabilities of the current atmospheric models to simulate stratospheric processes; this will allow scientists to predict with higher confidence the response of the ozone layer to natural perturbations, such as major volcanic eruptions or an extremely cold Arctic winter.

- Provide the scientific basis for identification of safe substitutes for the ozone-depleting substances (e.g., CFCs, halons, and hydrochlorofluorocarbons). NOAA will evaluate the ozone depletion and global warming potentials of proposed CFC substitutes using laboratory studies of reaction chemistry in tandem with atmospheric models and measurements. Monitoring the trends of the substitutes in the atmosphere will also begin.

- Elucidate the coupling between stratospheric ozone depletion and surface climate change by analyzing the radiative forcing associated with changes in the vertical ozone profile. Study the impact of changes in ultraviolet radiation on tropospheric chemistry and analyze the influence of indirect effects of ozone on greenhouse forcing.

Objective 5. ***Provide the scientific basis for improving air quality***

NOAA has a long record of studying acidic deposition and its precursors, both in the United States and globally. Laboratory and field studies have characterized many of the key process inputs to predict the air quality consequences of future scenarios of pollutant emissions and

controls. Several recent discoveries are the product of NOAA research, such as recognizing that elevated surface ozone levels in rural areas stem from the reaction of natural hydrocarbons with nitrogen emissions (often car exhaust) and characterizing the chemical processes and transport of constituents affecting air quality; and how acid deposition may affect sensitive ecosystems.

The early detection of cleaner air as a result of the Phase I reductions under the Clean Air Act requires that a monitoring network be in place prior to the onset of emission reductions. Furthermore, the role of rural ozone was not recognized in the preparation of the Clean Air Act Amendments. Hence, an improved implementation of the Act requires new research to guide its execution:

- Characterize both the human-influenced and natural emissions and processes that form ozone in rural areas. Field campaigns will establish where natural emissions of ozone precursors dominate over human-caused emissions. Predictions of which emission reductions are the most effective will be provided on a state-by-state basis.

- Conduct laboratory studies of processes creating surface ozone. Emphasis will be on the role of natural hydrocarbon emissions.

- Implement a monitoring network to will provide early detection of the air quality improvements resulting from Phase I emission reductions of the Clean Air Act Amendments.

- The atmospheric levels of the gases slated for reductions will be measured; trajectory and observation-based model studies of these gases will show changes in their levels. These studies will both elucidate the atmospheric processes influencing the gases and provide a cross-check on emission inventories. This work will improve predictions of how future emission reductions should be done.

- Predict results of Phase II emission reductions based on observations from the monitoring network and improved regional chemical transport models.

Objective 6. ***Provide prediction, assessment, and human impact information***

Climate change and ozone depletion assessments have become the standard mechanisms for providing science-based input to governmental decisions, but their utility to others could be improved markedly. To do this, NOAA must increase our understanding of the impacts of climate variability on human society and the ecosystems on which humans depend. Integrating the advancements in knowledge regarding the physical processes of the climate system with analyses of the socioeconomic context within which individuals, institutions, and economic sectors are vulnerable to climate fluctuations will provide valuable information for the decision-making needs and policy options of society. Studies being supported assess the

impacts of climate on resource management decisions and key economic sectors, such as agriculture, health, water resources, energy, fisheries, and transportation.

This effort will build on NOAA expertise and capabilities in marine and coastal regions, and will address high-priority USGCRP objectives. Pressing environmental and resource management issues, such as potentially irreversible climate change, and changing conditions in the availability of resources such as water, soil, and biological diversity are driving the need for improved information on possible climate impacts. NOAA is undertaking an integrated assessment of climate-human interactions and the use of climate information for decision-making in the US Pacific Northwest region where water management is and will continue to be of high concern. As part of its environmental prediction responsibilities, NOAA is a leader in the Global Ocean Ecosystem Dynamics (GLOBEC) Program, an interagency effort to determine the response of marine ecosystems and associated fishery resources to climate change. Recent efforts have focused on Georges Bank, where relatively small changes in ocean temperature can produce large changes in this economically important fishery region.

Further efforts will:

- Increase the focus on state-of-understanding assessments and expand the customer base. These new customers will include a broader scope of industries not yet influenced by assessment (e.g., the automobile industry and regional ozone science) and the general public (who are often misinformed on these topics). Outreach efforts also will focus on groups such as community leaders and educators as well as the general public. An extramural grants program will fund innovative and cost-effective education programs.

- Allow NOAA through its education/outreach efforts to continue its lead role among the CENR agencies in making valuable contributions to increasing the public's knowledge and understanding of the science related to climate and global change so they can react accordingly. In addition, NOAA will continue its postdoctoral fellowship program and monograph series.

- Focus on understanding the socioeconomic aspects of climate and global change, including the impacts of climate variability on human society and human adaptation. Interdisciplinary research combining the physical, natural, and social sciences will provide assessments of how climate change has affected and will affect individuals, industries, and societies and how human activities influence environmental change.

- Contribute to a better understanding of the impact of decadal-scale climate variability in the north Pacific on marine ecosystems. A strengthening of the Aleutian Low in 1976-77 has led to profound changes in ecosystem structure of the north Pacific which appears to have resulted in changes in fisheries stocks around the Pacific Basin.

NOAA will document past ecosystem changes and will initiate a monitoring program to characterize the present state of the ecosystem.

- Identify ecological systems that can provide valuable data on changes in the physical environment to complement physical monitoring. The recent and frequent bleaching of reef corals has inspired great interest in their possible use as indicators of regional to global scale stress.

CONCLUSION

It is widely recognized that NOAA has developed premier capabilities for understanding the forcing of environmental changes, the characterization of key processes involved, and the prediction of global and regional changes in all of the major current issues: natural climate variability, regional air quality, ozone-layer depletion, and greenhouse warming. The strengthening of these capabilities to meet the predictive needs for policy decisions in the next few years is one of the Nation's best environmental investments.

PROMOTE SAFE NAVIGATION

VISION

By 2005, merchant ships, naval vessels, fishing vessels, and recreational boats will safely ply our coastal waters, electronically guided by space-based navigation and advanced information technologies. NOAA will revolutionize U.S. marine and air navigation, mapping, and surveying and assist commercial shipping in moving increased cargoes safely and efficiently. NOAA will provide a precise satellite-derived reference system as the basis of its nautical data and for the Nation's geographic positioning needs.

THE CHALLENGE

Ships have doubled in length, width, and draft in the last 50 years and seagoing commerce has tripled, leading to increased risk in the Nation's ports. The advent of powerful, low-cost-computer systems and the Global Positioning System (GPS) enables dramatic changes in the practice of navigation. NOAA's legislatively mandated services in support of navigation and positioning must change to enable this revolution.

Essential Federal roles, including ensuring safety of the public, protection of the environment, and viability of the means to move commerce, must be carried out efficiently. These services are even more vital today than they have been in the past. Transportation, defense, international trade, science, public works, and other aspects of our society depend on these services. No other agency or organization in the country gathers these data or responds to these needs in the U.S. and its surrounding waters. Today, NOAA faces the prospect of being unable to discharge that responsibility effectively. The reasons are as follows:

- Products and services are growing inadequate due to lack of maintenance.

  More than 99% of U.S. international commerce outside North America, by weight, valued at nearly $500 billion, moves by ship. In our global economy, U.S. exports are expected to grow from about 22% of Gross Domestic Product today to over 30% in the year 2000. Half of today's marine cargo is oil or hazardous material. Increased dependence on foreign petroleum has dramatically increased the potential for disaster due to spills. From 1980-1988, tankers in the United States were involved in 468 groundings, 371 collisions, 97 rammings, 55 fires and explosions, and 95 deaths[16]. These ships move through the Nation's coastal waters guided by charts created with data that may be over 50 years old. Fully half of U.S. waters less than 30 meters deep (including 25% of our harbors and harbor approaches) were surveyed prior to World War II, when only a small fraction of the bottom could be sounded. Uncharted

[16] *No Safe Harbor: Tanker Safety in America's Ports* (Natural Resources Defense Council, New York, 1990).

obstructions, such as those encountered by the QUEEN ELIZABETH 2, may result in other accidents with more serious consequences. Tidal current prediction charts for several ports, including New York and San Francisco, have been withdrawn because, without maintenance, their accuracy had deteriorated to a potentially dangerous state. Modernization of the U.S. National water level measurement network remains only 55% done.

- User needs are changing because new navigation and positioning technology offers productivity gains.

  Presently, NOAA cannot provide the digital data required for rapidly emerging electronic chart systems. At sea, these systems reduce bridge workload by integrating information. More importantly, they can help to avoid accidents such as the EXXON VALDEZ disaster. Many deep-draft ships cannot enter U.S. ports except near times of high water. Real-time water level and current information is needed for safe navigation and to permit increased exports by maximizing use of limited channel depths. In the air, a new generation of navigation data sets will be required for air traffic control system modernization and the new satellite-based enroute navigation and instrument landing systems. On the ground, at sea, and in the air, the existing coordinate reference system must be revolutionized to take maximum advantage of the space-based GPS.

- Demand for geographic information to guide economic development and environmental stewardship is increasing.

  The annual national public expenditures for spatial data collection, maintenance, and manipulation were estimated to be about $7 billion in 1993. Development of the needed geographic data constitutes, on average, 80% of the overall cost of these GISs. This investment has limited value if the data are not exchangeable and based on accurate, compatible coordinates. Convenient, quick, and inexpensive access to a unified, consistent reference framework -- the National Spatial Reference System (NSRS) -- is necessary. Framework layers of the National Spatial Data Infrastructure (NSDI), including the NSRS as well as shoreline and bathymetry from the charting database, must be made available to a broad community.

SUMMARY OF OBJECTIVES

Objective 1. *Build, Maintain, and Deliver Digital Nautical Charting Database*

Accurate, reliable, and up-to-date nautical chart information is more important today, as margins are smaller and consequences greater, than at any time in the past. New electronic navigation systems can meet demands for greater protection of life, property, and the environment, as well as significantly improving efficiency. A digital nautical charting

database is needed not only to support these systems but also to improve the productivity of our chart-making process. NOAA's nautical charting program will be reinvented as the transition is made from traditional techniques to an automated digital process. The nautical charting database has been identified by the National Research Council as the component of the nautical charting process on which NOAA should focus its attention most intently.

Objective 2. ***Update Nautical Surveys***

NOAA must increase its hydrographic survey efforts to ensure up-to-date coverage of critical areas to ensure that they are safe for marine transportation. More efficient and effective hydrographic survey systems are required to improve productivity and sea floor coverage. Photogrammetric mapping of the coastline will be expanded to simultaneously characterize benthic communities and marine habitats, measure nearshore topography (for setbacks, zoning, erosion measurement, and hazardous material response), and delineate shoreline.

Objective 3. ***Provide Real-Time Observations and Forecasts of Water Levels, Tides, and Currents***

The national network of water level, current, water temperature, and meteorological sensors must be modernized to provide the data required for nowcasting and predicting in real-time and supplemented with sensors to measure currents at critical locations. Physical oceanography (tides, currents, and weather) measurements and measurement-based predictions will be made available in real-time to mariners and environmental planners in all key U.S. ports.

Objective 4. ***Develop the National Spatial Reference System***

New electronic navigation systems integrate electronic chart data with satellite positioning, as well as radar, sonar, and telemetered environmental information. In order to meet the Nation's navigation and other positioning needs, the existing coordinate reference system must be renovated to provide the higher accuracy and different accessibility needed for use with the Global Positioning System (GPS). The digital revolution in mapping, charting, and surveying requires a National Spatial Reference System (NSRS) consisting of the following components: (1) a network of monumented points having four-dimensional positions, (2) a set of GPS Continuously Operating Reference Stations (CORS), (3) high accuracy orbits of the GPS satellites, and (4) a highly accurate geoid. The NSRS provides a common geographic framework and the foundation for the Nation's spatial data infrastructure. The NSRS is the basis for mapping, charting, navigation, boundary determination, property delineation, infrastructure development, resource evaluation surveys, and scientific applications.

Objective 5. *Provide Modern Aeronautical Information*

NOAA provides instrument charts, visual charts, and special products and services for the Nation's pilots and air traffic controllers. NOAA maintains a perfect record of updating, printing, and distributing these products in conformance with the precise schedule needed to keep the National Airspace functioning safely and efficiently. The digital aeronautical navigation information database will be expanded to provide the necessary support for improved air traffic control in the U.S. NOAA will obtain and provide the navigation information necessary for operation with new generation satellite-based enroute navigation and instrument landing systems.

BENEFITS

SUPPORT OF NATIONAL GOALS

Accurate navigation and positioning services are essential components of the national infrastructure. In the words of President Clinton:

> "While our economic competitors have invested heavily in their infrastructure, we have not done as well. To regain our economic edge, we must invest more...put Americans back to work, spur productivity, and make transportation safer, faster, and easier for all Americans." (Vision of Change for America, February 17, 1993)

In addition, NOAA will make important contributions to the national information infrastructure by providing a foundation for the spatial information expected to flow on the Nation's information superhighways. This improved infrastructure will enable new value-added services and market opportunities in emerging spatial information industries.

This plan supports national goals, as follows:

- Supports the expansion of foreign markets and increases American exports by assuring that harbor and airport operations are safe and efficient. Improves the competitiveness of the commercial air and maritime industries.

- Enhances the development and commercialization of technologies for air and marine navigation, surveying, positioning, and the management of geographic information, thus strengthening American industries and creating jobs for American workers.

- Promotes sound environmental stewardship by providing basic environmental and geographic information for critical planning and management decisions for coastal and ocean resources.

- Promotes economic growth by opening new market opportunities and improving our transportation infrastructure.

BENEFITS TO THE NATION

These activities will increase the margin of safety against accidents at sea, in our Nation's ports, and in the air. Significant returns on investment in this activity will be realized in the form of broad societal gain, improved transportation efficiency, and development of markets ranging from GPS equipment to GISs. A 1% improvement in the overall efficiency of America's marine transportation system would translate into more than $2 billion in savings across our economy within a decade. The marine and air transportation industry; the survey community; managers, planners, engineers and scientists working in the coastal zone; and the general public will all derive benefits from application of the new technologies, products, and services by NOAA under this program.

Benefits include the following:

- Reduced risk of loss of life, cargo and other property, and environmental damage -- The consequences of providing erroneous or inadequate navigation-related data are severe and present significant potential liability to the federal government as well as posing unacceptable risks to users. Provision of accurate, up-to-date navigation information is one of the most cost-effective measures that can be taken to reduce the risk of accidents. As a Nation, we have made large commitments to safe navigation. Estimates of industry's cost for meeting the requirements to replace present single-hull tankers amount to upward of $100 billion, with about $20 billion attributable to the increased costs of double-hull designs. Double hulls should reduce the volume of oil spills by about 70%. Electronic charts, by comparison, are expected to prevent 15-19% of accidents with investments two or three orders of magnitude less.

- Increased productivity of maritime commerce -- The potential for cost savings and revenue increases related to improved accuracy and timeliness of critical information on currents and water levels can be significant. Real-time information on currents and water levels can avoid shipping delays that cost the industry as much as $3,000 per hour. Containership operations might reap as much as $6,000 to $24,000 in revenues for every inch of increased draft. Real-time water-level systems also have led to a tripling of coal exports from Philadelphia (from 1.5 to 5 million tons), an increase of 0.5 million tons of coal exports from Baltimore in the first year of operation, and an increase in grain exported from Portland amounting to $20,000 per shipload. Hundreds of millions of dollars are spent annually on dredging. Several hundred million dollars is expected to be spent for vessel traffic systems for major ports. Accurate, reliable physical oceanographic information and confident knowledge of underwater obstructions are relatively inexpensive and necessary to complement these National investments

- Improved response to marine spills of oil and hazardous materials -- When accidents or hazardous material spills occur in the marine environment, specific sets of data play a vital role in planning and managing the response. Shoreline and nearshore maps, together with environmental sensitivity data and oceanographic circulation predictions, are vital to protecting the environment successfully. The estimated ultimate cost of the EXXON VALDEZ oil spill is nearly $3 billion, and every year there are hundreds of smaller, but nonetheless significant, spills in U.S. coastal waters.

- Increased availability of consistent, accurate, and timely digital spatial data -- The National Spatial Reference System is the reference frame for the Nation's Geographic Information Systems (GIS) as well as navigation systems. Today's geodetic reference frame will be renovated to support full use of space-based techniques. The Federal Geodetic Control Subcommittee, under NOAA leadership, has been asked to serve as the GPS Interagency Advisory Committee. This advisory committee will strengthen the ties between the navigation and positioning communities, and ensure that the Nation's $10 billion investment in GPS serves both military and civilian users optimally.

- Improved planning and management of coastal and ocean resources -- The quality of public and private decision-making is improved by helping decision-makers envision or simulate the geographic realities they are addressing. GIS technologies are increasingly being used by Federal and state agencies for carrying out their missions of resource assessment, land management, socioeconomic analysis, planning, environmental monitoring, and disaster preparedness. Common standards and use of a common reference system enable increased sharing of data rather than limiting use to only the single purpose for which most data are gathered. Government agencies and companies can then concentrate efforts on using, rather than collecting, data. Recognizing this need, President Clinton, in April 1994, signed Executive Order 12906 calling for the development of a National Spatial Data Infrastructure (NSDI). The NSRS serves as the foundation for the NSDI. Bathymetry and shoreline data from the navigation database will serve as part of the framework of the NSDI. The estimated $7 billion annual public expenditure on spatial data in this country can be invested more effectively.

- Improved capacity, efficiency, and safety of our Nation's airspace -- A multi-billion dollar investment is being made to modernize the national airspace over the next decade, with the goal of reducing accidents by 50%. Airspace and airport capacity is projected to increase by 20% in 1999 and an additional 20% by the year 2005. A new generation of navigation data products is required to support the system and maximize its benefits to the country.

THE STRATEGY

RELATIONSHIP TO NOAA MISSION

NOAA's dual mission is to describe and predict changes in the Earth's environment. and to promote environmental stewardship. Navigation charts, the databases from which they are constructed, and the real-time oceanographic and meteorological measurements for navigation constitute some of the most basic descriptions of our environment. These data are being made available as the fundamental layers of a marine GIS in addition to being used for specific navigation products and services.

The challenge to NOAA is fulfilling its statutory mandate: "to provide charts and related information for the safe navigation of marine and air commerce, and to provide basic data for engineering and scientific purposes and for other commercial and industrial needs" (33 USC 883). This program carries on NOAA's historical role of describing our environment, protecting life and property, providing decision makers with reliable scientific information, and enhancing sustainable economic opportunities for the American people, particularly strengthening coastal economies. Maintaining and improving the safety and efficiency of our air and sea transportation systems provides the nation with a vital competitive advantage. Harnessing advances in technology in carrying out these functions maintains our world leadership in these areas.

Modern navigation and positioning services directly support environmental protection and stewardship by focusing on accident prevention rather than clean-up. These services also provide invaluable aid in contingency planning and improved means of responding to spills of oil and other hazardous materials when they do occur. Accurate positioning, precise delineation of shoreline, and determination of related boundaries are critical in coastal zone management as the basis for zoning and permitting. Coastal maps and water level information provide the basis for warnings of flood emergencies and long-term management waterfront development in the coastal zone.

OBJECTIVES

Objective 1. *Build, Maintain, and Deliver Digital Nautical Charting Database*

NOAA will improve nautical chart production versatility to enable delivery of data in any format, including electronic charts. Electronic Chart Display Information Systems (ECDIS) will provide a comprehensive set of navigational information and real-time ship's position on a clear graphic display on ships' bridges. ECDIS also can incorporate radar overlays to show other ships in the area and information from real-time tide, current, and weather data from systems such as PORTS. By digitizing the existing data base, implementing direct digital input of data into a central automated chart production facility, and developing more efficient and versatile software, NOAA will be able to take advantage of new electronic

information networks and data highways to maximize the effective use of vital navigation information even while continuing to provide traditional chart products. These data also will support marine GISs for integrated coastal management.

NOAA presently maintains a suite of nearly 1,000 paper nautical charts through traditional cartographic techniques. Although 380 charts are targeted for new editions annually, production under current conditions does not achieve that goal. The development of an automated charting system is nearing completion, but only a small fraction of the database required for full-scale automated chart production has been assembled. Only 50 of nearly 1,000 nautical charts have been digitized. At the present rate, it will take approximately 40 years to load the Automated Nautical Charting System II (ANCS II). In each of the past three years, legislation has been introduced in Congress that would mandate the use of electronic charts for certain vessels. The U.S. Navy, which relies on NOAA for navigation information in U.S. waters, has committed to standard use of electronic charts. The U.S. Coast Guard has cooperated with NOAA in evaluation of these systems and has demonstrated their value for its operations. The International Maritime Organization is about to approve their use. The Coast Guard, over the next year, will begin Vessel Traffic Systems in New York, Valdez, Puget Sound, and San Francisco. These systems will require digital chart data. NOAA, however, is not now able to deliver the digital data products to support these systems.

NOAA will review and update plans to reinvent the nautical charting process. The goal is to complete conversion to the automated charting system within five years. This system will be capable of maintaining traditional products, providing a new suite of digital electronic charts to support advanced navigation systems, and providing data for the base layers of a marine GIS.

Objective 2. ***Update Nautical Surveys***

The risk associated with marine navigation has become unnecessarily large. Approximately 43,000 square nautical miles of seafloor around the U.S. are in critical need of resurvey. These areas carry heavy commercial traffic, are less than 30 meters deep, and are known to be naturally changeable, or have reported chart inadequacies or outdated surveys. Fifty percent of surveys in waters less than 30 meters deep predate World War II. Twenty-five percent of the nation's harbor and harbor approach areas fall into this category. The technology used for those surveys sounded only a small fraction of the seafloor and, hence, those surveys probably have not detected all dangers to navigation. There is a backlog of 20,000 reported but uninvestigated obstructions to navigation, including 5,000 in critical areas. The number of hydrographic ships available for surveying has been reduced from five to three, and they are equipped with outmoded technology that samples only a small portion of the seafloor. At the present level of effort and with present equipment, investigation of obstructions reported in critical areas would require all available survey resources for the next ten years.

Approximately one-third of the U.S. coastline has never been mapped by photogrammetric methods and, of the shoreline that has been mapped, 25% predates 1970. Accurately delineated shoreline is critical for navigation, boundary determination, and other applications. There is no database today from which to assess damage from coastal hurricanes and other natural disasters, or monitor shoreline movement, erosion, development, or changes in wetland characteristics. NOAA operates two aircraft that carry out activities related to navigation and positioning programs. The Coastal Mapping Program conducts tide-coordinated photogrammetric mapping of the shoreline and coastal zone, including submerged aquatic vegetation and boundary demarcation. The Flight Edit and Airport Obstruction Chart Programs carry out evaluations of aeronautical charts and mapping of airport approach obstructions.

To produce and maintain up-to-date nautical charts, NOAA will rely on a mix of owned vessels and contracts for data. NOAA has also developed a strategy to enlist more productive, non-traditional techniques, such as airborne lidar and quick-reaction private sector contracts, in concert with modernized in-house capability. The NOAA vessels RAINIER, WHITING, and RUDE will continue to collect critical hydrographic data and information on obstructions and hazards to navigation. Modernization of survey launches will be undertaken to increase the quality and productivity of the data collection process. Coupled with increased contracts for data, these fleet modernization actions will move NOAA in the direction of achieving a 12 year re-survey cycle for the most critical 43,000 square nautical miles of navigable coastal waterways and harbors. These modernization efforts will contribute toward assisting commercial shipping in moving increased cargos safely and efficiently.

Photogrammetric operations will be modernized to meet multi-agency needs for official shoreline determination for the conterminous U.S. on a 5-year cycle. Aerial photography and multispectral scanner data will be acquired to characterize benthic communities and marine habitats, nearshore topography, and shoreline delineation to provide basic data for setbacks, zoning, erosion studies, hazardous material spill response, and other applications.

The goal is to provide modern coverage of the nation's most critical ports and harbor approaches within five years. The second goal is to complete, during the next five years, the first cycle of a systematic program to regularly resurvey critical areas of the Nation's coastline.

Objective 3. *Provide Real-Time Observations and Forecasts of Water Levels, Tides, and Currents*

NOAA provides tide and tidal current prediction tables, which are based on analysis of astronomical forces. These predictions do not account for the sometimes considerable effects of wind, river discharge, ice, and other atmospheric phenomena. The National Water Level Observation Network (NWLON), a network of 189 water level measurement stations

distributed along the marine and Great Lakes coasts and islands of the U.S., provides data for this analysis. A new generation of instruments has been developed to provide real-time information for storm warnings as well as navigation, but installation has not been completed.

Tidal current prediction charts for New York Harbor and San Francisco Bay have been withdrawn because they are no longer accurate. Over two-thirds of the 3,127 stations in the two tidal current tables that NOAA publishes are based on data that are over 40 years old. A single Physical Oceanographic Real-Time System (PORTS) serves Tampa, but NOAA lacks resources to implement this type of modern system in other areas. Similar systems have been requested by other U.S. ports, and some PORTS capabilities have been provided to the ports of New York/New Jersey; San Francisco, California; and Houston/Galveston, Texas. Without these systems, the risk of accidents and environmental damage is increased and opportunities are lost for improved productivity and increased exports.

NOAA will dramatically improve the oceanographic information provided to the maritime community by (1) implementing, in partnership with local interests, a national PORTS system, which will provide real-time, nowcasted, and predicted water level, current, and meteorological information in all major U.S. ports; (2) completing the modernization of the NWLON including completion of the Data Processing and Analysis System and the modernization of the National Tidal Bench Mark System; (3) modernizing tidal prediction products, services, and techniques, including the production of digital tidal prediction products; and (4) maintaining a National Water Level and Coastal Circulation Data Center. These capabilities are key components in the emerging technologies for integrated digital shipboard navigation systems as well as coastal prediction and management.

NOAA's goal is to provide a comprehensive marine prediction capability within five years. The NWLON will be modernized to provide real-time tide and water levels. The capability to provide real-time tide and current data (as well as wind and other meteorological data of importance to mariners and others) will be installed in ten major ports. Techniques will be developed for nowcasting and predicting based on real-time data. Digital tidal prediction products will be produced for at least five major estuaries.

Objective 4. ***Develop the National Spatial Reference System***

NOAA has maintained the Nation's positional framework by readjustment of geodetic data based on 150 years of observations. About 300,000 monumented points with horizontal positions referenced to the North American Datum of 1983 (NAD83) constitute the horizontal reference frame. The vertical reference frame is composed of nearly 600,000 stations with elevations referenced to the North American Vertical Datum of 1988 (NAVD88). This positional framework is difficult to maintain, control points are often inaccessible, and their locations are insufficiently accurate for today's needs. This system is obsolete.

The spatial data reference system needed today must fully support use of GPS for navigation and positioning. The new National Spatial Reference System (NSRS) will consist of the following components: (1) a network of monumented points having four-dimensional positions, (2) a set of GPS Continuously Operating Reference Stations (CORS), (3) high accuracy orbits of the GPS satellites, and (4) a highly accurate geoid.

NOAA is making progress toward the NSRS, responding to the demand for increased accuracy and accessibility to coordinates. In 70% of the states, NOAA has completed accuracy upgrades to the statewide networks of reference stations, with priority given to coastal areas. In partnership with the states, NOAA provides a basic high accuracy framework with 100-kilometer station spacing and assists with completion of more dense station spacing through support and technology transfer. To provide greater accessibility to the NSRS, NOAA is cooperating with other Federal agencies to establish a network of CORS to support differential GPS applications in navigation and positioning. The CORS being established by NOAA, U.S. Coast Guard, Corps of Engineers, and Federal Aviation Administration to support marine, river, and air navigation are being configured so that they also meet positioning needs of surveying, mapping, and GIS users. This meshing of navigation and positioning requirements, as a partnership under the NSDI, will assure spatial data consistency in the future.

NOAA's plan for the NSRS includes:

- National Earth Orientation Service (NEOS): NEOS provides an inertial (non-changing) geocentric cartesian reference frame for the NSRS, relates the NSRS to spatial reference systems developed by other nations, and provides the earth orientation parameters (polar motion, Universal Time, and nutation) required to compute GPS orbits. The inertial reference frame is based on observations collected by a global network of approximately 30 Very Long Baseline Interferometry (VLBI) stations that work cooperatively through the International Earth Rotation Service. GPS receivers collocated at the VLBI stations provide tracking data enabling NOAA to compute satellite orbits in this inertial reference frame, and ensure that GPS measurements made at different times are consistent and can be combined with all other data in the NSRS. NOAA will continue to participate, jointly with the U.S. Naval Observatory, in the operation of NEOS. NOAA's contributions will help ensure continued operation of southern hemisphere tracking stations. Using the GPS observations collected at the worldwide array of tracking stations, NOAA will also continue with daily computation of Earth orientation parameters and precise GPS orbits to provide fundamental orientation for the NSRS.

- Continuously Operating Reference Stations (CORS): CORS are fixed GPS tracking stations that operate 24 hours a day, 7 days a week, collecting observations that enable users to cost effectively utilize GPS techniques. CORS enable users to achieve the highest accuracy positioning of fixed and moving GPS receivers, minimize costs by

reducing or eliminating the need for project-related base stations, and ensure that new positional observations are accurately referred directly to the NSRS. Effective CORS operations require an accurate national geoid model to facilitate the use of GPS for precise leveling (i.e., the accurate determination of the height of a point above sea level). NOAA will receive and maintain GPS data from a network of approximately 100 CORS operating 24 hours a day, 7 days a week, to enable users to cost-effectively use GPS techniques. NOAA will provide positional integrity monitoring for the CORS network and efficient CORS data availability for users. NOAA's operation of the CORS data network will include development of an improved national geoid model to facilitate the use of GPS for leveling.

- Monumented reference stations: Monumented reference stations provide users with physical connections to the NSRS. The national network of monumented reference stations consists of points with certified latitudes, longitudes, elevations, and/or gravity values, together with estimates of their accuracies. These stations will continue to provide access to the NSRS for those users not yet using GPS in conjunction with CORS or other techniques, or where GPS cannot be used owing to skyward obstructions. They will also continue to be used for surveys as physical evidence to certify positions, e.g., to define political state or national boundaries. Monumented stations are required in crustal motion areas to ensure that valid repetitive observations are available to evaluate local and regional crustal motion, thereby providing time-dependent models for changes in the NSRS. While the existing NOAA database of monumented reference stations consists of nearly 1 million points, NOAA has identified its continued commitment for a Federal base network of approximately 1,300 high accuracy, three-dimensional stations established by NOAA, to be augmented by about 16,000 stations established through cooperative state and local government surveying agencies. Through these cooperative arrangements, NOAA will complete the establishment of the Federal base network in the remaining 30% of the states.

- Technology transfer: NOAA's technology transfer efforts will increase government and private sector productivity and effectiveness by providing the latest in state-of-the-art technology. Working through its Geodetic Advisor Program, NOAA encourages collaborative partnerships among Federal, state, and local governments, regional planning agencies, professional organizations, academia, and ad hoc groups. These partnerships foster opportunities to transfer advanced technology. Exploitation of the full capabilities of the NSRS is dependent on an outreach program to ensure that the latest technologies (e.g., GPS, bar-code precise leveling, data analysis, etc.) are readily available to the full user community and become the operational standards for positioning and other uses. To accomplish the required transfer of technology, NOAA will expand its geodetic technology outreach and Geodetic Advisor Program. NOAA will aggressively develop specifications to guide GPS users, develop and make available user-friendly computer software for processing and analyzing GPS and other observational data, and participate in cooperative projects that demonstrate the use of

GPS for diverse applications. NOAA will support cooperative research and training efforts with other governmental and academic organizations, and promptly report and demonstrate new findings through active participation in outreach programs, e.g., workshop activities and support of professional societies.

Objective 5. ***Provide Modern Aeronautical Information***

NOAA provides instrument charts, visual charts, and special products and services for the Nation's pilots and air traffic controllers. More than 9,800 charts and publications, nearly 80% of which must be revised every 56 days, are provided for pilots flying under Federal Aviation Administration (FAA) instrument flight rules. Two hundred and five different charts revised every 6-12 months are provided for pilots flying under visual flight rules. Special products and services that are provided include controller charts, obstruction charts, and radar video maps. NOAA also maintains a series of automated databases containing information on airports, obstructions, navigational aids, reporting points, and special use airspace. More than 30 gigabytes of data representing active features, graphic and chart change files are managed on-line in an advanced, distributed processing network.

The Nation's multi-billion dollar plan for modernizing the U.S. air traffic control system and shifting to GPS-based navigation requires further development of the aeronautical navigation information database -- digitizing of existing and new aeronautical charting projects. Existing technology is inadequate to meet these needs. NOAA will participate by digitizing the chart database to support analog graphics, flight publications, air traffic control, and airborne navigation system, and by developing software to support FAA and NOAA navigation products. This new effort will involve the creation of a national aeronautical chart database that will be able to receive new information and provide networked electronic access to new navigational data.

NOAA, in partnership with the two union locals involved, is presently evaluating the advantages of transferring its aeronautical charting functions to the proposed U.S. Air Traffic Services (USATS) Corporation or the FAA.

Related Objectives

Fleet Modernization

The proposed fleet modernization program is crucial to the success of NOAA's strategic plan goals. The plan is a dynamic document that is changed periodically to account for changing requirements, developing technology, and subsequent alternative ways of acquiring data and carrying out program missions. NOAA fleet modernization promises to substantially increase data quality, productivity, and operational efficiency.

Research

Vigorous research is a critical underpinning to NOAA's efforts to promote safe navigation. Efforts include geodetic research on dynamics of the earth and space bodies, marine navigation risk assessment through Sea Grant, physical oceanographic modeling and forecasting, spatial data and cartographic system research, and hydrographic survey system development. These research efforts also provide crucial support to other NOAA goals. The precision of GPS orbits, for instance, now enables satellite altimetry to detect the El Niño-Southern Oscillation events involved in seasonal to interannual climate change. Water vapor estimates required for improving short term weather forecasts can be derived from GPS measurements as a result of geodesist's efforts to eliminate its effect on position measurements. VLBI enables measurement of crustal motion and, thus, absolute sea level rise associated with decadal climate change. Submerged aquatic vegetation important to fisheries habitat can be characterized with advanced photogrammetric techniques being developed for shoreline mapping.

Data and Information

Coastal zone GISs are becoming essential tools for managing the coastal environment. The basic data layers for these systems are key elements of the NSDI, as described in Executive Order 12906, and are built from the same data that support the representation of the seafloor and shoreline on nautical charts, as well as circulation information for navigation. Use of these data will provide a common reference and avoid unnecessary duplication. NOAA will support and lead these applications. NOAA works closely with a group of 14 other Federal agencies as members of the Federal Geographic Data Committee (FGDC) to coordinate this effort. The objectives are to (1) make available, by the year 2000, the framework digital spatial data sets needed by GIS users to support effective decision-making; (2) minimize duplication of effort and redundant, incompatible data sets; and (3) work in full partnership with state and local governments and the private sector. NOAA is identified as the lead agency responsible for development of the spatial reference system, the official photogrammetrically determined shoreline for the conterminous United States on a 5-year cycle, and establishing a comprehensive digital nautical information database of U.S. coastal waters by the year 2000. The Federal Geographic Data Committee has designated NOAA as the lead agency to supply shoreline, bathymetry, and geodetic data for use across the Federal government. As the nautical chart database is updated and new survey technologies are introduced, database management systems will be implemented to provide the products needed by GIS users. High resolution photogrammetric and bathymetric data will be collected to map resources, hazards, and ecosystems.

CONCLUSION

By 2005, merchant ships, naval vessels, fishing vessels, and recreational boats will safely ply U.S. coastal waters, electronically guided by space-based navigation and advanced

information technologies. NOAA will revolutionize U.S. navigation, mapping, and surveying, and assist commercial shipping in moving increased cargo through U.S. ports and harbors with unsurpassed safety and efficiency. While maritime navigation will always be hazardous, the new technologies promise to significantly reduce the risk of accidents and spills. By revolutionizing America's marine transportation infrastructure, these technologies will heighten the competitiveness of the U.S. shipping industry and inject new vitality into the Nation's economy. The technologies will be critical in supporting the environmental stewardship roles of coastal zone planners, regulatory officials, and researchers as they work to ensure the safe, sustainable, and efficient development of U.S. coastal and ocean resources.

ENVIRONMENTAL STEWARDSHIP

MISSION

For 2005,

NOAA envisions U.S. ocean and coastal areas with healthy ecosystems and the wise human use and development of ocean, coastal and living marine resources.

BUILD SUSTAINABLE FISHERIES

VISION

NOAA's vision for the next decade is to increase the Nation's wealth and quality of life for Americans by ensuring sustainable fisheries that provide safe seafood, a healthy fishing industry and recreational opportunities. This vision requires sound biological, economic, and social information to focus policy decisions, rather than allowing scientific uncertainty to fuel controversy and confusion. It includes implementation of ambitious Fishery Management Plans (FMPs) prepared by eight Congressionally established Fishery Management Councils to resolve problems of uncontrolled participation in fisheries, overcapitalization, overfishing and resource depletion, controversial allocation decisions, and wasteful bycatch of non-target species. Efforts to ensure the sustainable use of fishery resources will provide long-term economic opportunities.

To support implementation of this vision, NOAA proposes developing partnerships with those affected by or interested in our living marine resources (LMRs), including Congress, Fishery Management Councils, and the industry itself. Together we must derive innovative approaches that mitigate inevitable short-term costs during rebuilding so that our efforts will be implemented and repaid many times over in the long term. The vision includes the application of new methods and solutions, such as growth in a U.S. marine aquaculture industry as a tool to help restore depleted populations, effective international agreements to conserve and manage transboundary LMRs, and technical assistance to developing countries to promote global LMR stewardship and geopolitical stability.

THE CHALLENGE

Overfishing and overcapitalization in commercial and recreational fisheries have resulted in billions of dollars foregone in potential economic benefits, as well as in hundreds of thousands of jobs, countless recreational fishing opportunities, and potential reductions in the Nation's multi-billion dollar trade deficit in fishery products. Even those fisheries that are producing a large catch are doing so inefficiently. U.S. fisheries are also the subject of extremely controversial allocation decisions between elements of commercial and/or recreational fisheries, in some cases requiring action at the highest levels of the Federal government and resulting in costly litigation for society. Lack of dependable data on economic and social benefits and costs associated with fishery management proposals compounds the problem for decision-makers.

Still other fishery resources are under utilized. As of 1995, the National Marine Fisheries Service (NMFS) reported that of 201 fishery resources, 28% were overutilized and 15%

were under utilized[17]. There is insufficient scientific information to assess 22% of all U.S. fishery resources (Figure 1). U.S. fisheries are also impacted by bycatch of non-target species, including marine mammals and endangered species of sea turtles, which are killed accidentally by some common fishing methods. Finally, commercial fishing claims many lives each year as fishermen fish under unsafe circumstances to reap maximum benefits under current resource and regulatory conditions.

Many of the causes of problems that plague fisheries today can be traced to the tradition of uncontrolled participation in most U.S. fisheries (i.e., open access) resulting in serious over-capitalization. This is exemplified by more vessels or increasingly efficient vessels racing to catch fewer and fewer fish. Attempts to limit the catch in the short term have traditionally been met with stiff opposition because already economically stressed fishery participants cannot afford to cut back catch. But doing so is the prescription for long-term economic and ecological health. Uncertainty in scientific information compounds the problem by fueling arguments that cutting back is unnecessary. When faced with opposition from the fishing industry and uncertain information, it has been common for fishery managers to make risk-prone decisions, which eventually lead to detrimental economic, social, and ecological consequences. Bycatch and allocation decisions similarly are made more problematic because of overcapitalization and uncertain scientific information.

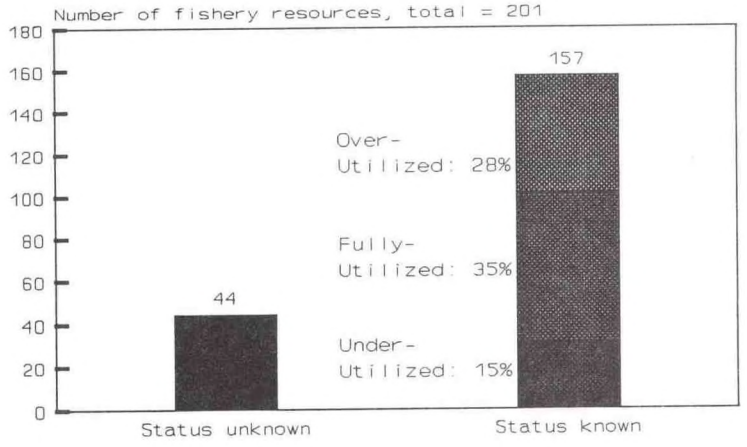

Figure 1 -- Status of Resources

While building sustainable fisheries requires more and better scientific information and new resources to develop different fishery management systems, NOAA's vision also requires innovative approaches to help the fishing industry and affected coastal communities cope with short-term losses that occur during the rebuilding period. Assistance levels provided to the industry can and should be set in accordance with expected benefits that will accrue in the long term.

Long-term assistance will take the form of developing technologies that promote sustainable fisheries. One tool that could be used is aquaculture. Aquaculture technology has the potential to enhance production of wild stocks of fish and shellfish as a means of accelerating

[17] *Our Living Oceans: Report on the Status of U.S. Living Marine Resources, 1995*, NOAA Technical Memorandum NMFS-F/SPO-19 (U.S. DoC, NOAA, National Marine Fisheries Service, February 1996).

recovery of depleted stocks. However, the U.S. lags behind the rest of the world in production of seafood by marine aquaculture. Globally, aquaculture is a growth industry that accounts for about 15% of fishery production, whereas it is only about 6% of marine fishery production in the U.S.

Rebuilding fisheries and accelerating development of aquaculture will produce more raw material for the seafood industry. However, impediments to the optimum use of these LMRs must be addressed in NOAA's vision. For example, consumers must be confident that seafood is safe and of high quality. The National Academy of Sciences in its 1991 report, *Seafood Safety*, stated that most seafood is safe and unlikely to cause illness in consumers; however, there remain areas of risk. Appropriate management and control of seafood safety are needed to provide public health protection as well as to maximize net economic benefits to society.

Finally, U.S. responsibility for stewardship of fishery resources involves achieving or maintaining regional and international agreements to fulfill stewardship commitments made at the United National Conference on the Environment and Development (UNCED) and elsewhere. Worldwide, fisheries are a more important source of animal protein than beef, pork, lamb, or poultry. Millions of lives and the geopolitical stability of some regions depend on sustainable use of fishery resources either for domestic consumption or as a source of income through trade, and the U.S. LMRs that NOAA manages are part of the global ecosystem and a global economy. For many developing countries, sustainable use requires technical assistance from the U.S.

SUMMARY OF OBJECTIVES

NOAA proposes five objectives. The five objectives are dependent on one another; each relies on components of the others for its success and has little context without progress in the other objectives. The specific elements of the objectives discussed herein must be implemented concurrently to realize the full potential of the plan.

Objective 1. ***Assess the status of fishery resources***

This objective addresses the serious problem of inadequate information on the condition of fishery resources. This information is needed by the Fishery Management Councils and DOC Secretary for equitable and legally sound regulatory decisions for 33 current, and additionally proposed, FMPs. The objective provides the scientific basis of policy options for rebuilding the Nation's fisheries.

Objective 2. ***Advance fishery predictions***

The long term potential benefits of the Nation's fisheries are ultimately limited by the current scientific methods that are available as a basis for fisheries management. To advance fishery

predictions and improve information to support stewardship responsibilities, a better understanding of the physical and biological processes that control ecosystem dynamics is required. This effort aims to improve understanding of the factors that influence fish populations and the functions and relationships of habitats to living marine resources to improve predictions of fisheries productivity.

Objective 3. ***Manage for economic growth and sustainability***

NOAA must evaluate, select, and monitor management measures that have the greatest benefit to the nation, such as FMPs that eliminate the traditional open-access nature of most U.S. fisheries, overcapitalization, and the self-destructive "race for the fish." The long history of overutilization, excess fishing effort, and resource depletion in many of the Nation's most valuable fisheries must be reversed.

Objective 4. ***Ensure adequate compliance***

Once regulations are in place, sustainable fisheries can only be fully achieved with adequate regulatory compliance. The steady increase in the number of FMPs, complex regulatory regimes and the competition for fewer fish have made it necessary for NOAA to improve its ability to respond effectively to increased compliance problems.

Objective 5. ***Provide research and services for fishery-dependent industries***

This objective addresses the need for NOAA to provide uniquely governmental forms of research and assistance to fishery or seafood-related industries to maximize the potential benefits from the Nation's marine resources. NOAA will develop strategies to assist local coastal communities in adapting to short- and long-term changes in resource access and availability to ensure the sustained health and viability of these communities. Aquaculture technologies for marine species, for both enhancement and commercial production purposes, will be developed. NOAA will also foster technology development and national and international agreements to support both conservation and economic goals.

BENEFITS

SUPPORT OF NATIONAL GOALS

This plan addresses the stated Administration and DOC goal of a sustainable environment combined with a sustainable economy. It seeks to rebuild and sustain the Nation's stocks of LMRs while supporting the viability of the Nation's fishing economy and communities.

BENEFITS TO THE NATION

In 1993, U.S. commercial fisheries produced $3.5 billion in revenues to fishermen at U.S. ports, with a total (direct, indirect, and induced) impact on the economy of about $38.1 billion. The latest U.S. aquaculture data indicate that production in 1992 was valued at $724 million at pondside, providing an ultimate economic impact of close to $4 billion. In addition, roughly 17 million American anglers caught more than 293 million fish, taken on an estimated 53 million fishing trips. But many more benefits are possible.

This plan is structured on a fishery-by-fishery basis to achieve the full potential benefits from U.S. fishery resources. NOAA's analysis of the long-term potential economic benefits of rebuilding overfished fisheries, eliminating overcapitalization, and fully utilizing currently under utilized resources indicates the potential increase in net revenues is $2.9 billion per year. This is net of the investment needed in science and research to support NOAA's stewardship role. The annual impact on the national economy (direct, indirect, and induced) associated with rebuilding fisheries is about $25 billion, including an $8 billion impact on the gross domestic product and about 300,000 jobs[18]. This will lead to increased tax revenues of about $1 billion from the harvesting sector alone as it becomes profitable, much more if the flow of fisheries' profits to other investments is included. In addition, aquaculture for stock enhancement has the potential to produce billions of dollars of economic growth and hundreds of thousands of new jobs.

If the plan is fully implemented, benefits that will be realized include:

- Sustainable fisheries, stability in the marine ecosystem, and healthy, renewable use of the Nation's LMRs
- An economically healthy fishing industry, which will increase the U.S. tax base and tax revenues from the harvesting sector by about $1 billion
- Less loss of life and property during commercial fishing by eliminating the dangerous and wasteful "race for the fish"
- Opportunities for many more Americans to enjoy the benefits of recreational fishing
- A reduction in the U.S. trade deficit and establishment of a more stable seafood processing industry
- A steady supply of high-quality domestic seafood

[18] Sissenwine, M. and S. Swartz, 1992. *Analysis of the Potential Economic Benefits from U.S. Fisheries* (U.S. DoC, NOAA, NMFS, Internal Report of the Office of the Senior Scientist).

- Fewer illnesses and deaths associated with seafood consumption
- Increased public confidence in and knowledge of seafood products
- An improved investment climate and fewer market gluts
- A system to allow market forces to determine fishery resource allocations
- Reduction of bycatch mortality and recovery of such protected species as dolphins and sea turtles, as fishing practices and technology become more responsive to conservation principles and the law
- Development of industries to utilize previously discarded species and fishery waste and a subsequent reduction of waste of fishery products
- Fewer allocation conflicts and controversial management decisions that require the Secretary's attention or result in law suits against the DOC
- Restoration of credibility and public trust in government with respect to fishery management and enforcement, and minimization of legal challenges
- Reduction of the negative environmental impacts of aquaculture and other fishery activities
- Expansion of the U.S. marine aquaculture industry with decreased dependence on the sensitive coastal zone
- Use of aquaculture to enhance depleted stocks of capture fisheries, in combination with stock management, shortening the recovery time for over-exploited fisheries
- Sharing of U.S. scientific and fishery management expertise with developing countries, improving the health of millions of people, saving many lives, and enhancing geopolitical stability
- Demonstration that the U.S. is a nation that is committed to honoring its international obligations under UNCED and other global and regional agreements.

THE STRATEGY

RELATIONSHIP TO NOAA MISSION

Management of LMRs is the primary means for NOAA to fulfill its mission of promoting global environmental stewardship. NOAA is the only Federal agency with specific statutory

authority to conserve and manage the fishery resources found off the coasts of the United States (including highly migratory and anadromous species) under the Magnuson Fishery Conservation and Management Act (Magnuson Act) of 1976. NOAA's stewardship responsibilities require it to assess the impact of anthropogenic activities and natural changes on the health and sustainability of marine ecosystems. Specifically, the Magnuson Act requires the Secretary of Commerce to establish and conduct the Nation's marine fishery conservation and management program.

OBJECTIVES

NOAA is uniquely positioned to accomplish the five objectives described below. The best trained and by far the largest corps of world class assessment scientists and fishery managers resides in NOAA. In addition, NOAA's fleet of fishery research ships, while deteriorating, is the Nation's largest and most effective. NOAA also has extensive partnerships with states and other Federal agencies. These NOAA capabilities and those of its partners, including their ties to the Nation's university community, represent perhaps the world's greatest intellectual base to address the complex problems confronting fisheries.

Objective 1. *Assess the status of fishery resources*

Each year NOAA reviews the status of more than 231 fish, marine mammal, and sea turtle stocks. NOAA is seeking to improve its recreational and commercial fishery data collection on all coasts and has begun the design and development of a new nationwide computer system to manage the millions of individual data observations acquired each year. Where vessels of more than one nation participate in a fishery, there must be international cooperation to obtain these data.

Of the 201 species assessed recently by NMFS[19], the status of stocks for 22% is unknown. Future plans include improving the quality and quantity of catch and bycatch data for commercial and recreational fisheries, conducting at-sea observer data collection, conducting resource surveys, conducting population biology studies, analyzing and modeling fishery and ecosystem data, and utilizing advanced data management technology.

The optimum mix of these components is fishery-specific. Factors such as degree of stock depletion, multi-species interactions, number and diversity of harvesters and gears, and the nature of a stock's biology will affect the degree to which each element is needed for a fishery. NOAA is now using innovative techniques to identify the point of diminishing return on investments to assure that funds are used effectively to provide a high benefit/cost ratio.

[19] *Our Living Ocean: Report on the Status of U.S. linving Marine Resources.* op.cit.

- Collect and manage catch and bycatch data for commercial and recreational fisheries

  Data are the primary building blocks for assessing the status of fisheries and developing policy options for fishery management. Data are also used directly in fishery management as a basis for catch allocations and to determine when allowable catch levels have been reached. Improvement in the quality (accuracy and precision) and quantity of recreational and commercial catch and bycatch data is a fundamental requirement to better understanding of the impacts of fisheries and the development of subsequent management decisions to regulate fisheries.

- Conduct at-sea observer data collection

  To monitor adequately the impact of harvesting on a particular species, as well as on the ecosystem as a whole, it is important to estimate the overall catch by vessels on the fishing grounds (both targeted and bycatch species), not just the portion of the harvest that is ultimately landed and sold. The best means for obtaining unbiased information on what is removed from the system (i.e., killed) by fishing is through data collected by at-sea observers. These observers estimate the catch and provide real-time monitoring of the progress of the fishery. At-sea observers are required for both domestic fisheries, operating under FMPs, and international fisheries, under negotiated agreements to monitor quotas and incidental take. They obtain data unavailable by other means on the species, size, sex, and other biological characteristics of both target and non-target species eventually landed or discarded at sea. This includes samples of protected species such as marine mammals and sea turtles that might be bycatch to the fishery. This information is vital for the development of comprehensive management and conservation programs.

- Conduct resource surveys

  Standardized field programs sample the distribution and abundance of fishery resources in order to monitor trends. Surveys are conducted by NOAA research vessels, and sometimes in association with contracted state, university, or private vessels. These surveys provide a fishery-independent measure of resource abundance, are used to calibrate the performance of fisheries over time, and are a critical part of assessing resource status and the impact of the harvest sector on the ecosystem. Resource surveys can be made more precise in several ways, such as increasing sampling intensity or spatial and temporal coverage, improving sampling designs, and improving sampling technology. This plan proposes using all of these methods to improve resource surveys and the precision of assessments, as appropriate, on a fishery-by-fishery basis over time. These surveys are critical for assessing the status of resources and biodiversity and of the impact of the harvest on the ecosystem.

- Conduct population biology studies

  NOAA scientists and managers must have a comprehensive understanding of the biology, stock structure, and migratory patterns of fishery resources. Information needs include: stock identification; age structure; knowledge of interdependency between recovering, depleted, and healthy fish stocks; and reproductive habits and habitat requirements. NOAA currently conducts extensive research on this type of biology. However, for many species, especially those newly exploited, the current state of biological knowledge is poor.

- Analyze and model fishery and ecosystem data

  Fishery management depends on mathematical models and statistical analyses to integrate the available data from the activities described above into a quantitative scientific basis for decisions. These analyses use state-of-the-art models of population dynamics and risk assessments to formulate policy options for fishery management. NOAA needs to develop new methods to use data more efficiently, better quantify uncertainty in the results, analyze complex multi-species fisheries, and develop and apply risk analysis to decisions.

- Advance data management technology

  Large quantities of valuable data, critical to the overall objective of managing the Nation's marine resources more effectively, must be managed so that they are accessible, easily manipulated, and archived for future use by NOAA and other users. NOAA has a comprehensive, long-term plan for advancing data management to meet these goals which includes plans to:

  - Develop new distributed application software to take full advantage of the computing power of hardware and new relational database software.

  - Continue to rescue historical data crucial for resource management decisions and retrospective analyses.

  - Improve public access to data by expanding the use of metadata, on-line access, and various forms of electronic publishing and information dissemination to increase electronic access to data on the LMRs, the environment and its biodiversity.

Objective 2. ***Advance fishery predictions***

NOAA has already initiated regional studies to model important aspects of population recruitment and multi-species interactions for key fisheries. It supports fundamental research on fish behavior and distribution, and ecosystem research to determine how the physical

environment influences both short- and long-term population status. NOAA also supports academic research aimed at improving the capability for predicting yields, assessing population status, and studying various aspects of fishery biology ranging from genetics, physiology, and behavior to population and community dynamics. Yet, important research remains to be done for NOAA to move more fully into comprehensive, ecosystem management.

The major components of this action include advancing understanding of coastal fishery ecosystems, integrating non-fishing related anthropogenic stress into fishery assessments, and advancing sampling technology.

- Advance understanding of coastal fishery ecosystems

  Better prediction of future fishery yields will depend upon the development of better ecological models that incorporate mechanisms of population control, natural environmental fluctuations, and multi-species interactions. One important use of such models is to determine when or if overfishing has irreversibly changed the structure of marine ecosystems. Important information must be obtained on the physical environment, predator-prey relationships, and basic recruitment processes.

- Integrate non-fishing-related anthropogenic stress into fishery assessments

  There is a need to develop a method of distinguishing biological stress due to non-fishing-related anthropogenic sources from the stress resulting from fishing. Many potentially harmful substances enter our coastal waters via discharges, runoff, groundwater, and deposition from the atmosphere. At present, there is no quantitative measure of the cumulative effects of toxins on population declines in the marine environment that may result from acute toxicity or subtle reductions in growth, reproduction, or viability. The key to this new approach is the identification of a common currency of stress to fishery populations that lends itself both to the fields of bioeffects and population dynamics.

- Advance sampling technology

  The next generation of ecosystem models will require specialized types of data that cannot be collected adequately in terms of quantity or quality with existing technology. Automated instruments transmitting near continuous observations to ships or shore-based laboratories are particularly needed for the large amount of biological data used in ecosystem modeling. Similar technology advances are needed for resource surveys used to assess fisheries. While the instrumentation for remote physical measurements has developed rapidly, comparable biological sensors have proved more difficult to implement. To address this problem, NOAA proposes to investigate several state-of-

the-art technological systems deemed to have significant potential for remote sampling of biological populations.

Objective 3. ***Manage for economic growth and sustainability***

Ocean fish are the last public resource that can be used for private gain by anyone who can afford the technology required. Most marine fish management has been directed to setting catch quotas, seasons, size limits, and legal gear definitions in attempts to protect the fish stocks. Allocating fish with the traditional fishery management tools is clumsy and legally contentious. An ideal solution is to combine the necessary traditional regulations to conserve the resource with free market methods to allocate fish among competing users. One alternative is to assign negotiable shares of the total allowable catch to individuals. These individual shares can be traded in free and competitive markets, similar to land or business franchises. After the initial distribution of access rights, the free market will allocate the rights among individuals according to who uses them most efficiently.

Successful transformation from conventional, open access to profitable, controlled-access fishery management will require significant improvements in information monitoring and management, and increased social and economic research. In this context we need to better understand the behavior of fishermen rather than of fish. Conversion to controlled access to rebuild stocks will cause short-term economic hardships for some harvesters and processors, with subsequent effects on coastal community stability. NOAA must work cooperatively to develop strategies to assist the affected constituencies during periods of stock rebuilding.

For the U.S. to achieve full potential economic benefits from its fishery resources, NOAA, working with the Fishery Management Councils, the fishing industry, foreign nations, and coastal communities, must:

- Develop fishery management strategies that rebuild the stocks.
- Establish a LMR management climate that minimizes overcapitalization.
- Encourage prudent investment in fisheries for currently under utilized resources.
- Establish systems that resolve open access inefficiencies and promote market forces to help determine access to fisheries.
- Develop strategies that enable the fishing industry and coastal communities to endure the dislocations that will occur during stock rebuilding periods.

The major components of this objective are collecting and analyzing economic and social data, developing and implementing controlled-access plans, promoting a healthy fishing

industry and coastal communities, and supporting global stewardship thus fulfilling UNCED commitments.

- Collect and analyze economic and social data

  NOAA lacks adequate social science data collection, management, and analytical capabilities to keep up with the expanding need to evaluate socioeconomic issues associated with its fishery conservation and management responsibilities. While analyses of economic and social impacts of management regulations are required by statute, such requirements have outstripped the current data and analytical in-house capabilities of NOAA. Currently, fishery managers cannot quantify the economic efficiency and welfare distribution consequences of their actions. This puts the fishery resources at greater risk of decline because the behavioral and market responses to fishery regulations cannot be predicted. The inability to quantify and explain economic benefits and costs associated with proposed controlled-access management will severely jeopardize constituent understanding and acceptance of these regimes. To address these shortcomings NOAA proposes to:

  - Develop social and economic impact models for application to specific U.S. fisheries.

  - Expand baseline economic and social data and profiles of commercial, subsistence, and recreational fisheries.

  - Establish basic social and economic performance measures for use in impact assessments under the Magnuson Act, related laws, and Executive Orders.

  - Determine how marketable property rights affect the economic performance of the fishing industry.

  - Design and evaluate management regimes to reduce conflict and achieve more efficient and equitable allocation of fishery resources among competing users.

- Develop and implement controlled-access plans

  Experience in developing current controlled-access plans, and the experience of other countries, indicates that substantial new and different technical support will be necessary to prepare functional FMPs. Specifically, NOAA proposes to:

  - Develop educational programs for Council members and the fishery industry to better underscore the merits of controlled-access fishery management and to highlight potential problem areas.

- Conduct in-house and contracted social and economic research on the Nation's fisheries to provide alternatives for consideration by the Councils in developing management schemes.

- Carry out specialized economic, social, and legal analyses to support specific decisions on initial allocations, the nature of property rights, options for setting quotas, and other decisions required for controlled-access management.

- Promote a healthy fishing industry and coastal communities

  In the long term, developing sustainable fisheries is the essential ingredient of a healthy economy, for industries that support commercial and recreational fisheries and the communities where they are located. But today's U.S. fishing industry is not healthy, as a result of overfishing, resource depletion, and open access fisheries that have led to overcapitalization. In the short term, while depleted fishery resources rebuild and the size of fishing fleets adjusts to a level that maximizes resource productivity, it is inevitable that some segments of the fishing industry will face transition costs.

  NOAA has recently implemented short-term emergency assistance programs dealing with the Northeast groundfish and Northwest salmon fisheries. However, demands for such assistance are likely to increase as more management measures to reverse the declines in fish stocks are implemented. NOAA needs to develop a long-term strategy for addressing future industry assistance needs, including tailoring assistance to the specific region and causes of the impact on fishing, identifying national and local program management responsibilities, and determining the need for legislative action. All solutions will require a consensus between public constituents, the fishing industry and government.

- Support global stewardship by fulfilling UNCED commitments

  Approximately two years ago, the U.S. and many other nations made commitments at the Earth Summit to take actions toward environmentally sustainable development. An 800-page blueprint for action, Agenda 21, was adopted. Many of its actions are within NOAA's purview and areas of expertise, most notably conservation and management of fishery resources. In addition, NOAA supports U.S. membership in eight international institutions that manage LMRs as well as participating in other international fisheries negotiations. NOAA's approach is to use its vast technical expertise to lead in international planning and coordination, and to leverage other funds to help developing countries implement sound stewardship, including human resource development, so that

NOAA's effort will provide sustainable benefits. NOAA proposes to:

- Systematically identify a pool of expertise that will be used to provide technical assistance in developing countries.

- Formalize and expand arrangements with donor agencies, such as the Global Environmental Facility of the World Bank and the U.S. Agency for International Development, to provide technical expertise to assure the success of funded projects.

- Form partnerships with international organizations, such as the Food and Agricultural Organization and the International Oceanographic Commission, to plan and implement international programs, such as the Global Ocean Observing System, that enhance stewardship.

Objective 4. ***Ensure adequate compliance***

Productive fisheries can become unproductive because of inadequate compliance with regulations. Many existing regulations are hard to enforce, and given NOAA's limited enforcement resources, obtaining adequate compliance is difficult.

The effectiveness of a strong enforcement presence as a powerful deterrent to lawlessness, with its associated costs to society, is as well established for fisheries as for conventional police forces. NOAA's chief ally, the U.S. Coast Guard, has increased its efforts to provide effective at-sea enforcement of fisheries laws. However, the Coast Guard is a multi-mission organization with many other responsibilities. To complement these responsibilities, NOAA must increase its dockside presence nationwide.

NOAA has begun to expand its enforcement program by adding a shoreside compliance force and is studying other areas for improvement. The major components of this effort are:

- Strengthen shoreside (uniformed officers and agents) and other enforcement staff to increase the number of inspections, patrols, and boardings.

- Develop appropriate systems for inspecting, monitoring, and tracking catches and effort under controlled-access systems.

- Modernize enforcement operations by upgrading equipment, data collection, and retrieval systems.

- Routinely assess the degree of compliance with fishery management regulations, evaluate the factors that have contributed to non-compliance, and relocate enforcement resources accordingly.

- Implement education and outreach programs to foster an environmental stewardship ethic and to provide better information to fishermen about regulations, thereby decreasing the incidence of inadvertent violations.

- Negotiate to achieve international acceptance of principles concerning fisheries for straddling stocks and highly migratory species and to ensure compliance of all fishermen with international conservation measures.

Objective 5. ***Provide research and services for fishery-dependent industries***

NOAA supports a variety of research efforts that benefit fishery-dependent industries. For instance, NOAA administers the Saltonstall-Kennedy program, which provides grants to carry out research and development projects that address harvesting, processing, infrastructure, or other significant fishing industry concerns. NOAA also supports research toward the development of state-of-the-art fishing gear and academic research aimed at improving the capability in marine aquaculture. NOAA carries out a seafood science program to address technical impediments to the optimum use of LMRs and is pursuing the elimination of tariffs and non-tariff trade barriers in bilateral and multilateral international negotiations. To reduce wasteful fishing practices, NOAA is working with industry to develop a National Industry Bycatch Coalition to coordinate and enhance industry's involvement in and funding of bycatch research.

NOAA provides financial services to the fishing industry through programs that improve access to capital, compensates fishermen whose gear or vessels have been destroyed by foreign or domestic vessels in the U.S. Exclusive Economic Zone (EEZ), and compensates fishermen for losses related to oil and gas exploration, development, and production on the Outer Continental Shelf. It has recently implemented programs in the Northeast and Northwest to assist the fishing industry in adjusting to the management measures instituted for allowing stocks that have been overfished or subjected to environmental impacts to rebuild to more productive levels. Finally, NOAA has leveraged millions of dollars of funding from the World Bank and the Global Environment Facility to help developing countries assess and manage their large marine ecosystems by providing technical expertise and by negotiating international agreements which pursue the elimination of tariffs and non-tariff barriers.

The three main elements of this objective are reducing bycatch by advancing conservation engineering, accelerating the growth of U.S. marine aquaculture, and addressing impediments to the optimal use of LMRs.

- Reduce bycatch by advancing conservation engineering

  While the issue of bycatch has been recognized as a significant factor in the accurate assessment of stocks, bycatch species are often an important biological component of

ecosystems; their removal can be wasteful from an economic perspective, undermines conservation efforts, reduces biodiversity and may change the composition of ecosystems in ways that inhibit recovery of fish stocks. Thus means of reducing bycatch must be identified, developed, and implemented.

The Magnuson Fishery Conservation and Management Act, as amended in 1990, directed the DOC to conduct research in the field of "conservation engineering," which includes the development of highly selective harvesting gear. Development of gear that will not catch non-target species is needed for some fisheries (e.g., Pacific halibut in Alaska trawl fisheries), while in others, gear must be developed that will permit non-target organisms, such as undersize swordfish taken on longline, to escape unharmed if captured.

- Accelerate the growth of U.S. marine aquaculture

Production of fish through aquaculture has the potential to help rebuild depleted fish stocks and provide a steady supply of high-quality domestic fishery products to U.S. consumers. Successful development of this emerging industry will require a merger of NOAA's scientific and technical expertise with private industry's capital and support.

The Act that established the National Sea Grant College Program (PL 89-688) specifically identifies marine aquaculture as Sea Grant's mandate, and NMFS and its predecessor agencies have sponsored aquaculture programs for over 100 years. However, U.S. aquaculture has grown at a slower rate than in many other parts of the world, due to a lack of funds for development, concern over use of the coastal zone for sitting aquaculture facilities, lack of appropriate production technology, and restrictive policy and regulations. This plan concentrates on technology that will allow U.S. aquaculture to move out of the sensitive coastal zones into onshore or offshore locations with technology that minimizes environmental impacts. In addition, NOAA will develop technology for using aquaculture to enhance natural populations of key aquatic species and will evaluate the technical and economic feasibility of this technology. Specifically NOAA will foster the development of environmentally acceptable, cost-effective, intensive commercial aquaculture systems and advance NOAA's fishery enhancement programs through the development of new hatchery rearing systems and the tailoring of candidate species for those systems, using biotechnology and other scientific approaches.

- Address impediments to the optimal use of LMRs

The optimal use of LMRs includes using fish as food. Therefore, NOAA addresses issues relating to the safety and quality of fishery products, and to technical and trade barriers precluding optimal use. The major components of this action are:

- Research to detect and control hazards: NOAA will continue development of methods to detect, control, and eliminate pathogenic microorganisms, biotoxins, and chemical contaminants in seafood products, under its Product Quality and Safety research program and extramural grants.

- Research to optimize resources through science and technology: NOAA will improve energy and processing efficiency in producing fresh, frozen, and canned products; collate and communicate Federal, state, and local regulatory requirements and associated penalties relating to environmental quality that affect seafood processors; develop technology for water conservation, waste management, and effluent control, and conduct pilot experiments and demonstrate new or improved technology.

- Fair market access: Access to international markets for U.S. fishery products will continue to be improved through negotiations and cooperative programs or arrangements in international fora, such as the recently concluded Uruguay Round GATT negotiations and APEC; and in bilateral negotiations, such as the annual U.S./Japan negotiations, U.S./E.U. negotiations regarding accession of EFTA countries to the E.U., and GATT accession negotiations. International markets for non-traditional U.S. products will also be identified to minimize waste and increase the value of U.S. catch.

CONCLUSION

This plan is based on a systematic evaluation of each U.S. fishery to estimate the requirements of a coordinated series of scientific and management activities, which collectively form a complete system (from data collection to enforcement of regulations) to achieve NOAA's vision. These evaluations were aggregated for all fisheries into five objectives.

NOAA must act immediately to prevent additional economic loss to the Nation and to help the fishing industry realize new opportunities and profits. Not only are the potential benefits from building sustainable fisheries high, but the Nation risks substantial losses through inaction as more resources become overfished. We need to better understand the dynamics of the natural resources being managed and also have a much clearer comprehension of their responses to human actions and of human responses to the cycles of ecosystems. To restore long-standing deficiencies in NOAA's scientific infrastructure will require a long-term commitment of resources to research and implement solutions. The long-term benefits of the initiative are predicated on a continued investment of new funds over the next five years.

Since 1977, when the U.S. extended its jurisdiction over the largest EEZ of any nation, NOAA's funding has not increased to the level needed to fulfill its new legal mandates. NOAA must continuously balance the growth in its responsibilities by obtaining the resources

necessary to execute them. The need for and degree of additional resources required is well documented by several studies including the 1990-1994 National Fish and Wildlife Foundation's *Fisheries and Wildlife Assessment* series, reports and Congressional testimony of three Interstate Marine Fisheries Commissions, Marine Advisory Committee recommendations, and the 1989 Audubon Wildlife Report on the National Marine Fisheries Service. In fact, the need is increasing as Fishery Management Councils develop more ambitious plans. Within the next two years, many of the Nation's fisheries will begin to come under controlled-access systems. In addition, many migratory coastal resources that formerly were managed by individual states came under cooperative interjurisdictional management with the implementation in 1993 of the Coastal Migratory Fish and Management Act. There are significant additional costs associated with the science, research, and information necessary to implement each of these activities.

Effective fisheries management is premised on the collection of accurate and timely data on the health and abundance of stocks. Stock assessment surveys and research carried out at sea provide the baseline data for the development of fisheries management plans by the Regional Fisheries Management Councils. NOAA's fisheries research vessels, coupled with charters, provide the primary means for the collection of this critical data. Currently, eight dedicated fisheries research vessels support this mission -- the MILLER FREEMAN, OREGON II, DAVID STARR JORDAN, DELAWARE II, TOWNSEND CROMWELL, ALBATROSS IV, JOHN N. COBB, AND CHAPMAN. As these existing vessels age, they will need to be replaced with newer, more modern vessels to continue this important function. NOAA's Fleet Replacement and Modernization (FRAM) Plan envisions the need for six modern vessels, government owned or leased, to provide for the long-term continuity of fisheries data collection. Additional data collection efforts will be met through increased use of chartering of university and private vessels.

Through increased resource productivity and improved efficiency of their use, the fishery management systems envisioned by NOAA are a good investment that will produce tremendous long-term benefits. If the financial resources are provided, the implementation of plans that generate these benefits will accelerate. If not, Federal stewardship will be discredited, future opportunities and benefits will be lost, and living marine resources will be put at risk of economic and biological extinction.

RECOVER PROTECTED SPECIES

VISION

NOAA's vision is to conserve all marine species and their habitats, and to recover those that are threatened or in danger of extinction. By 2005, NOAA will be on the road to recovering every marine species at risk and maintaining healthy marine ecosystems upon which they depend.

THE CHALLENGE

Past natural resource use policies have led to the loss of many marine species, and many of those remaining are facing the threat of extinction. Since the Pilgrims landed at Plymouth Rock in 1620, more than 500 of the Nation's plant and animal species have become extinct. One of those species was Steller's Sea Cow, the largest marine herbivore known to have occupied our Nation's coastal waters, once exploited for its meat and blubber. By contrast, 3,000 years of Pleistocene Ice Age drove to extinction only three species every 100 years. The current threat to marine species remains significant.

West coast salmon populations are at risk due to a combination of factors that include habitat loss and commercial over-exploitation. Despite required protective measures, fishing-related mortality continues to threaten marine turtles in U.S. waters. Several sea lion, seal, and sea bird populations in the Bering Sea and Gulf of Alaska are declining rapidly, and the causes are uncertain.

Numerous and complex factors contribute to the decline of living marine resources. Contributing human factors include the loss or degradation of habitat; mortality resulting from incidental capture in fishing operations; offshore oil, gas, and mineral development; coastal development; commercial and recreational ship traffic; hatchery operations; and water diversion projects.

The solutions to the problem are more elusive than the symptoms. A lack of scientific information upon which to base decisions complicates effective resource protection. The sources and levels of direct and indirect mortality attributable to interactions with commercial fishing and other industrial activities are often poorly understood. The cumulative effects of long-term exposure to various anthropogenic activities (e.g., coastal development, seismic exploration, offshore mineral development, and non-point pollution) on protected species also are largely unknown. Climatic and oceanographic influences on the abundance and distribution of protected species that are poorly understood. The causes of mass stranding or episodic die-offs of dolphins and whales that have occurred in recent years along the U.S. Atlantic and Gulf coasts and around the world are also unknown.

Without accurate information on which to base decisions regarding the use of marine resources, these decisions can have disastrous consequences for protected species and reduce the options for recovering them. For example, the construction of numerous dams on the Columbia River system was a primary cause of the decline in wild salmon, and now their operations restrict the options available for salmon recovery. The over capitalization of many fisheries in previous times, coupled with the decline of commercial stocks, now makes some fleets less flexible and able to change gear or practices even though interactions with protected species have been documented.

Similarly, a lack of information can lead to severe restrictions on commercial or recreational opportunities in marine ecosystems when it is necessary to protect endangered species. Such restrictions may have a major adverse impact on local economies, particularly in small, coastal communities where harvest or use of marine resources forms the foundation of the economy.

SUMMARY OF OBJECTIVES

NOAA's stewardship responsibility is to ensure that our national treasure of marine biodiversity will be protected and enhanced for future generations. To accomplish this goal, NOAA will develop and implement conservation programs to protect at-risk marine species. Conservation programs rely upon a solid investment in research and decision-making to support actions to conserve endangered, threatened, and depleted marine species protected under the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). Research and management are two sides of the integrated program NOAA has designed in response to the Nation's mandate to conserve living marine resources. NOAA will concurrently address the public's interest in resource protection and economic development, national priorities, and its statutory responsibilities under the ESA and MMPA to provide effective leadership to:

Objective 1. ***Develop and implement conservation programs***

NOAA will conserve marine species by developing and implementing conservation and recovery plans. NOAA will accomplish this objective in cooperation with Federal, tribal, state, and local partners. To do this, NOAA will strengthen its capabilities to identify and protect marine resources facing extinction and will provide leadership to develop conservation and recovery programs that consider the resource and habitat needs of marine species in conjunction with sustainable economic opportunities in the marine environment. NOAA will provide leadership and assistance through its scientific, educational, and technical capabilities to implement recovery plans and thereby ensure that protected resources remain for future generations. A significant portion of the activities under this objective will implement research and management actions to mitigate or avoid detrimental interactions between marine species and human activities.

Objective 2. ***Assess status and impacts***

NOAA will assess and predict the status of protected species and barriers to their recovery. The intent of this objective is to strengthen the scientific basis for decision-making. NOAA will produce the information and analyses necessary for assessments of the status and trends of protected marine species and the impacts of those factors responsible for their decline. These assessments will be quality controlled and produced in formats and time frames useful to decision-makers as they implement actions under Objective 1. NOAA's protected resources research program will develop a better understanding of the linkages between living marine species and their environment. Thorough knowledge of the status of species and assessments of those factors causing decline will assist in resolving conflicts between marine resource users without having to resort to overly restrictive conservation measures.

BENEFITS

SUPPORT OF NATIONAL GOALS

One of the key goals of the Department of Commerce is to ensure and enhance sustainable economic opportunities for the Nation and to ensure that economic prosperity and environmental quality are compatible goals. NOAA, as part of the DOC, is committed to solving marine resource issues through cooperation with stakeholders on all sides of the issues. NOAA will integrate both administration and DOC goals into its mission to manage the Nation's marine resources and recover the species and habitats that have been degraded.

This program will make NOAA the leader in preserving marine biodiversity by balancing our exploitation of natural resources with the conservation of species. NOAA will provide scientifically sound stewardship of the Nation's living marine resources and promote the long-term health of marine ecosystems. Stewardship of the marine environment will ensure that future generations of Americans have a rich diversity of marine life for their consumptive and non-consumptive enjoyment.

BENEFITS TO THE NATION

Conservation of the Nation's living marine resources will enhance economic opportunities for future generations. This program will protect and restore those marine species that the American people have affirmed to have great value. Marine species are useful to humans for medicinal purposes, as monitors of environmental quality, and as key components of ecosystems that support a broad array of economically valuable resources. Marine resources in regions such as the Pacific Northwest are its capital. A significant sector of the economy depends upon healthy marine ecosystems for long-term economic development.

President Clinton and Vice President Gore have stated repeatedly that the economy and the environment are inextricably linked, and that a healthy economy and a healthy environment

are mutually dependent. NOAA will cooperate with its Federal, tribal, state, and local partners to involve them in the planning and implementation of species recovery actions. NOAA will make accurate, informed decisions about resource protection based on improved assessments and analyses. The benefit of these efforts will be an effective balance of species protection with sustainable marine resource exploitation and U.S. economic development.

THE STRATEGY

RELATIONSHIP TO NOAA MISSION

NOAA's effective stewardship of the marine environment will ensure that future generations of Americans have a rich diversity of marine life for their consumptive and non-consumptive enjoyment. NOAA's efforts to recover protected species are an integral part of its mission to promote global environmental stewardship and to describe and predict changes in the Earth's environment. The effort utilizes NOAA's research and management expertise to understand and quantify how species, ecosystems, and biological diversity are affected by human impacts and to implement effective programs to recover species or prevent their decline while minimizing the impact to affected users. This effort will contribute strongly to other elements of the NOAA Strategic Plan, particularly Build Sustainable Fisheries and Coastal Ecosystems Health. The Build Sustainable Fisheries element seeks to harvest fishery resources in a manner that maintains marine ecosystem biodiversity and is compatible with the conservation of protected species. The Coastal Ecosystems Health element strives to achieve and perpetuate healthy coastal ecosystems and economic prosperity through improved science, more effective management, and a better educated public.

OBJECTIVES

NOAA's vision to conserve and recover marine species in danger of extinction while maintaining healthy ecosystems upon which they depend is encompassed by its objectives to: (1) Protect marine species by developing and implementing conservation and recovery programs, and (2) monitor, assess, and predict the status of protected species and their ecosystems. NOAA's current and future actions in support of these objectives are described below.

Objective 1. ***Develop and implement conservation programs***

Protected species conservation and recovery programs seek to reverse negative population trends to return species at risk of extinction to healthy, ecologically functional levels within marine ecosystems. To date, 28 marine species and a number of their population subsets are listed as threatened or endangered under the ESA or depleted under the MMPA (Table 1). NOAA has developed conservation and recovery programs for 11 of these species. While many recovery plans have been approved, other species do not yet have approved plans. None of the current conservation or recovery plans have been fully implemented. This

requires more than NOAA can accomplish alone. Successful conservation of protected marine resources requires the cooperation of other government agencies and private organizations whose actions affect nearshore and offshore marine ecosystems, and where populations range across the territorial boundaries of more than one country. NOAA must pursue greater interagency cooperation at the international, Federal, state, native American, and private levels; work to incorporate the valuable opinions and experience of conservation organizations and user groups; and develop partnerships to build on new ideas to sustain ecosystem health.

The major actions to implement this objective, along with recent examples of progress in these areas, are:

- Develop and implement conservation and recovery programs for protected species that consider the full range of alternatives and evaluate the potential social and economic impacts of actions.

  - NOAA released its draft recovery plan for Snake River sockeye, spring/summer chinook, and fall chinook salmon. This plan outlines those comprehensive measures necessary to recover these stocks.

  - NOAA is a party to the San Francisco Bay/Delta Ecosystem Partnership in California, which is an agreement among four Federal agencies to provide reliable water supplies for California, protect threatened chinook salmon and delta smelt, and avoid the necessity of listing additional species.

  - NOAA has expanded its efforts to recover sea turtles beyond the Atlantic and southeastern U.S., into the Pacific Basin. Sea turtles are highly migratory, traveling great distances between nesting and foraging habitat, and species are declining because of incidental capture in commercial fisheries as well as other threats.

  - NOAA has established a regional program to protect the critically endangered North Atlantic right whale in the U.S. Atlantic through a program developed jointly by NOAA, the U.S. Navy, Coast Guard, Corps of Engineers, and state agencies of Georgia and Florida.

  - NOAA has worked to increase the role of state governments to protect and recover ESA-listed species, has established cooperative agreements under Section 6 of the ESA with three states (Georgia, South Carolina, and New York), and is negotiating agreements with several other states and territories.

  - NOAA works with Federal agencies, states, tribes, and other affected and interested parties in the Pacific northwest to undertake recovery actions for endangered

salmon. These actions respond to the primary cause of salmon decline: harvest, hydropower, habitat, and hatchery operations.

- NOAA is working with the Fishery Management Councils, Atlantic States Marine Fisheries Commission, and Canadian officials to assess the impact and reduce the mortality of the Gulf of Maine harbor porpoise from commercial fishing operations.

- In 1994, NOAA issued six joint policies with the U.S. Fish and Wildlife Service to implement the ESA more effectively. These policies improve coordination and cooperation with other Federal and state agencies and constituent groups to conserve and recover protected species.

- Develop and enforce necessary conservation regulations, after consideration of potential benefits and impacts, and identify and develop technology to reduce commercial interactions with protected species.

  - NOAA has made substantial progress in eliminating the major human cause of turtle mortality at sea by requiring year-round use of turtle excluder devices (TED) by shrimp trawlers fishing in southeastern U.S. waters. TEDs are an example of appropriate technology, developed by NOAA and the fishing industry, which allows trawling to continue while allowing sea turtles to escape unharmed.

  - NOAA was involved in developing and implementing actions under the 1994 MMPA amendments that created a new regime to govern interactions between marine mammals and commercial fishing operations. This new regime sets a goal of reducing incidental mortality to sustainable levels within two years and to rates approaching zero within seven years.

- Develop and implement international agreements to conserve protected species and their ecosystems.

  - NOAA provides leadership to implement a variety of international conventions, including the Inter-American Tropical Tuna Commission and the International Dolphin Protection Program with regard to the international tuna fleet operating in the eastern tropical Pacific Ocean.

  - NOAA cooperates and participates in national and international efforts to analyze and develop interpretations of trade rules to allow for the use of trade measures in support of conservation objectives.

  - NOAA is a major participant in the International Whaling Commission and implements its conservation programs, including aboriginal subsistence harvests of bowhead whales in Alaska.

- NOAA implements the Convention on International Trade in Endangered Fauna and Flora, with respect to marine species, the Convention on Biological Diversity, the Decade of Discovery under the Summit of the Americas, and the International Coral Reef Initiative to conserve coral ecosystems.

- NOAA is negotiating a convention for sea turtle protection in the western hemisphere with its Federal partners and foreign governments.

In support of its objective to protect marine species with conservation and recovery programs, NOAA will:

- Develop and implement proactive measures to prevent the need for additional species listings; encourage other agencies and entities to take measures to conserve candidate species.

- Develop monitoring programs to evaluate the success of recovery programs and revise existing conservation and recovery plans, as appropriate.

- Establish conservation and recovery plan implementation teams, made up of representatives of affected Federal and state agencies, industries, and public interest groups, to develop cooperative strategies to plans; the plans will provide guidance to conserve and recover species while minimizing adverse impacts on users.

- Emphasize the development of multi-species or ecosystem-based recovery plans or programs, consider broad environmental impacts in species planning activities, integrate the requirements of the National Environmental Policy Act, and further the goals of maintaining biodiversity and ecosystem health.

- Promote and increase cooperation with other Federal agencies, foreign governments, and international organizations in developing and implementing conservation strategies; explore the full range of NOAA authorities that could contribute to species conservation; and encourage other Federal agencies to use their authorities to promote the conservation of species.

- Improve Section 7 (ESA) consultations with Federal agencies, focus on efficient means to expedite the consultation process, identify actions in early planning stages to minimize adverse impacts to endangered or threatened species, and monitor implementation of reasonable and prudent measures.

- Encourage expansion of state agency roles in conservation and recovery actions, emphasize the development of cooperative agreements with States under Section 6 of the ESA, and develop a mechanism to prioritize funding.

- Develop cooperative management and conservation programs with Alaska natives and Native Americans to ensure the conservation of marine mammals and endangered and threatened species; recognize treaty obligations and MMPA provisions afforded Alaska natives under Federal law.

- Implement greater education and outreach programs to inform constituents and stakeholders about current protected species issues and efforts to resolve resource conflicts; develop partnerships and incentives for participation of stakeholders in conservation efforts.

Objective 2. ***Assess status and impacts***

NOAA is committed to strengthening the scientific basis for its protected species decision-making by gathering the information and performing the analyses necessary for assessments of the status and trends of protected marine species and identifying and assessing those factors responsible for species decline. Status assessments include analyses of stock structure and distribution, the abundance and trends of populations, and identification of essential habitats. Assessments also identify principal sources of direct and indirect mortality attributed to human activities. To advance beyond single species management, NOAA will invest more in long term research to better understand the biological and physical forces driving the dynamics of protected species populations. This investment will include research on population dynamics, new technologies for monitoring populations, and the integration of oceanographic and climate information with historical information on the distribution and abundance of species. These broad based research activities will establish the foundation of NOAA's future conservation efforts for living marine resources.

The major actions to implement this objective are:

- Conduct status reviews to determine whether or not to list species as depleted, endangered, or threatened and to designate critical habitat. Ensure the best available scientific information is used in these determinations, incorporating peer review as necessary.

- Conduct long-term monitoring including surveys and tagging studies to determine the distribution, seasonal movements, reproductive rates, abundance, and trends of protected species. Maintain current data on the status of protected species populations and produce in formats and time frames useful to decision-makers.

- Explore new technologies to improve NOAA's ability to assess the status of protected species and to further understand their basic biology and natural history.

- Develop and implement observer programs to monitor and verify incidental takes of protected species associated with commercial and recreational activities.

- Identify fisheries that have adverse interactions with protected species and implement conservation measures to eliminate or mitigate mortality, including long-line, gill net, and other trawl fisheries.

- Maintain protected species stranding networks and research to obtain information on natural or human-induced mortalities; respond to die-off events involving large numbers of animals to determine causes of such events and their impacts.

In support of its objective to bring the best possible scientific information to bear on protected species decision-making, NOAA will:

- Maintain a protected species database and provide quality-controlled information and analyses in formats and time frames useful to decision-makers in local to national scales.

- Continue to advance beyond single species management and invest in long-term ecosystem-level research to better understand factors critical to protected species recovery.

- Develop fully integrated multi-species research programs to identify components of biodiversity and to understand the interrelationships and dynamics of protected species and their marine ecosystems.

- Integrate information on climate, physical oceanography, and marine biology to better understand the linkages between protected species and the communities in which they function.

- Design working models of the structure and dynamics of marine ecosystems that account for natural and human pressures within the ecosystems.

- Investigate new technologies for monitoring the movements and behavior of individuals and populations.

- Use NOAA's capability to evaluate and provide information to guide policies and actions related to marine species conservation.

Ships collect data necessary for monitoring the health and abundance of endangered and protected marine species. Marine mammal surveys are conducted primarily by ships at sea using observers and helicopter support. NOAA's fisheries research vessels, along with contracts and university vessels carry out this important activity. The NOAA vessels primarily involved in marine mammal surveys are the TOWNSEND CROMWELL, DAVID STARR JORDAN, and McARTHUR.

CONCLUSION

The success of NOAA's vision to protect all marine species and to recover those in danger of extinction depends on a continued investment in sound science and decision-making. Developing and implementing conservation and recovery programs to recover species at risk of extinction and to restore their marine ecosystems will also benefit those of us who depend on marine resources for our livelihood, whether it be fishing, tourism, or transportation. Successful conservation of protected marine resources requires the cooperation of other all stakeholders, including government agencies, conservation organizations, user groups, and individuals, whose combined knowledge and experience are necessary for effective partnerships in conservation. The basis for effective conservation of protected species is scientifically based decision-making. NOAA will collect the information, produce the assessments, identify and assess those factors responsible for species decline, and provide this information to decision-makers. With a better scientific basis for its decision-making, NOAA can decrease the need for conservative solutions that protect resources at risk but are made with an absence of adequate data, which may unnecessarily restrict marine users and the economic benefits they might realize.

TABLE 1. STATUS OF PROTECTED SPECIES

SPECIES	STATUS	PLAN STAGE	PROBLEM CAUSE/ISSUE
Blue Whale	Endangered	None	Severely depleted by commercial whaling
Bowhead Whale	Endangered	None	Subsistence hunting and offshore oil and gas development
Fin Whale	Endangered	None	Severely depleted by commercial whaling
Humpback Whale	Endangered	Final	Entanglement in fishing gear and collisions with ships
Right Whale	Endangered	Final	Entanglement in fishing gear, collisions with ships, and habitat degradation
Sei Whale	Endangered	None	Severely depleted by commercial whaling
Sperm Whale	Endangered	None	Severely depleted by commercial whaling
Steller Sea Lion	Threatened	Final	Subsistence, prey depletion, and entanglement in debris
Monk Seal	Endangered	Final	Habitat loss, and entanglement in fishing gear
Northern Fur Seal	Depleted	Final	Prey depletion, subsistence
Guadalupe Fur Seal	Threatened	None	
Bottlenose Dolphin	Depleted	None	Entanglement in fishing gear
Green Turtle (Atlantic/Florida)	Threatened/ Endangered	Final	Commercial fishing and habitat degradation
Green Turtle (Pacific)	Threatened	Draft	Commercial fishing and habitat degradation
Hawksbill Turtle (Atlantic)	Endangered	Final	Beach development and habitat degradation

SPECIES	STATUS	PLAN STAGE	PROBLEM CAUSE/ISSUE
Hawksbill Turtle (Pacific)	Endangered	Draft	Beach development and habitat degradation
Leatherback Turtle (Pacific)	Endangered	Draft	Commercial fishing and habitat degradation
Leatherback Turtle (Atlantic)	Endangered	Final	Commercial fishing and habitat degradation
Olive Ridley Turtle	Threatened	Draft	Commercial fishing and habitat degradation
Kemp's Ridley Turtle	Endangered	Final	Commercial fishing, and habitat degradation
Loggerhead Turtle (Atlantic)	Threatened	Final	Commercial fishing and habitat degradation
Loggerhead Turtle (Pacific)	Threatened	Draft	Commercial fishing and habitat degradation
Gulf Sturgeon	Threatened	Final	Recreational fishing and habitat degradation
Chinook Salmon (Sacramento)	Threatened	None	Habitat degradation
Shortnose Sturgeon	Endangered	None	Habitat degradation
Chinook Salmon (Snake River Fall)	Threatened	Draft	Habitat degradation
Sockeye Salmon (Snake River)	Endangered	Draft	Habitat degradation
Chinook Salmon (Snake River Spring/Summer)	Threatened	Draft	Habitat degradation

SUSTAIN HEALTHY COASTS

VISION

By 2005, the Nation's coasts will have more productive and diverse habitats for fish and wildlife, and cleaner coastal waters for recreation and the production of seafood. Coastal communities will have thriving, sustainable economies based on well-planned development and healthy coastal ecosystems.

THE CHALLENGE

The coast, where the land and rivers meet the sea and Great Lakes, is a special, valuable, and complex place. Fish, marine mammals, shorebirds, and other wildlife make their home in coastal watersheds, estuaries, or the deeper waters of the continental shelf. Access to coastal recreation, maritime commerce, and resource-based jobs such as fishing make the coast an attractive place for people to live. While progress has been made in the last twenty years in protecting coastal resources, many areas and resources continue to experience environmental decline. Information about the causes, effects, and interactions among multiple stresses to coastal ecosystems is largely unavailable, despite the critical need to develop comprehensive management solutions. Unless specific steps are taken to restore and protect the health of the Nation's coastal ecosystems, the long-term prognosis is continued decline with serious economic and environmental consequences for current and future generations.

The reasons for coastal environmental decline are numerous and complex, but population growth and the cumulative effects of human activities affecting coastal areas are significant factors. Not only does over 50% of the U.S. population live on only 10% of the land area that is coastal, but these populations are growing at a faster rate than those inland. For example, along the Gulf of Mexico and Pacific coasts, populations have more than doubled since 1960, and the population of eastern Florida has increased more than four fold.[20]

Coastal habitats such as wetlands and riparian areas are essential to over 75% of the total commercial landings and 80-90% of the recreational catch of fish and shellfish of the continental U.S.[21] The productivity and diversity of these habitats provide the fuel to drive fisheries and other sectors of coastal economies. These habitats are being lost or are showing clear signs of stress. Coastal wetlands are being lost at an estimated rate of 20,000

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[20] Cullitan, T.J., et al., *50 Years of Population Change Along the Nation's Coasts 1960-2010.* Coastal Trends Series Report 2 (U.S. DoC, NOAA, National Ocean Service, April 1990).

[21] *Habitat Protection Activity Report 1991-1993* (U.S. DoC, NOAA, National Marine Fisheries Service, August 1994).

acres per year.[22] Coastal Louisiana accounts for a disproportionate share of this loss (i.e., 80%).[23] Forty percent of all coastal wetlands in the U.S. are found in Louisiana and those wetlands are being lost due to inundation and erosion primarily from sea level rise, extensive canal dredging, and sediment deprivation from flood control levees on the Mississippi River. The quantity and quality of coastal wetlands elsewhere in the country are seriously affected by point and nonpoint sources of pollution such as wastewater treatment plants and runoff from urban and agricultural sources.

Over one-third of the shellfish-growing waters of the U.S. are harvest-limited, including half of Gulf of Mexico growing waters, due primarily to coastal pollution.[24] Fish species dependent on coastal habitats have been reduced to historically low levels by over-fishing, habitat loss, and habitat deterioration from pollution and alterations in freshwater flows. In the Great Lakes, fish advisories are printed on every fishing license because large sport fish carry enough toxins to be risks to human health. These biological problems threaten significant sectors of the U.S. economy. For example, commercial fisheries produce $3 billion in revenue to fishermen and generate $38 billion in economic activity nationally. Seventeen million Americans who enjoy recreational fishing, generate an estimated $18 billion in economic activity.[25]

Disruptive changes in the biological composition and structure of coastal ecosystems raises serious concerns. Changes in biological diversity can be an indicator of stress on coastal ecosystems. The loss of diversity can mean the permanent loss of information and materials critical to progress in biomedical and other fields. Changes in biodiversity are frequently signs of other shifts in coastal ecosystems. For example, overfishing and destruction of habitat in the Pacific Northwest threaten the genetic diversity and future viability of several salmon species. Biodiversity shifts caused by the introduction of nonindigenous species also threaten the integrity of coastal ecosystems and pose serious economic consequences. For instance, zebra mussels that clog water intakes have caused an estimated $3 billion in economic losses in the ten years since their introduction into the Great Lakes.

Coastal recreation and tourism are a significant sector of the U.S. economy and depend on good environmental conditions such as clean coastal water for swimming and fishing. In

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[22] *Habitat Protection Activity Report 1991-1993* (U.S. DoC, NOAA, National Marine Fisheries Service, August 1994).

[23] Boesch, D.F., et al., "Scientific Assessment of Coastal Wetland Loss, Restoration and Management in Louisiana," *Journal of Coastal Research*, No. 20, (May 1994).

[24] *The 1990 National Shellfish Register of Classified Estuarine Waters* (U.S. DoC, NOAA, National Ocean Service, Strategic Assessment Branch, July 1991).

[25] *Fisheries of the United States, 1993*, Current Fisheries Statistics No. 9300 (U.S. DoC, NOAA, National Marine Fisheries Service, May 1994).

Monroe County, Florida alone, which includes the Florida Keys, saltwater fishing and tourism generate nearly half a billion dollars annually.[26] In 1994, foreign visitors to the U.S. spent $78 billion largely in coastal locations. For example, fifteen percent of foreign visitors went to Miami, Florida and nineteen percent to the Hawaiian Islands.[27] Such expenditures by foreign visitors is significant to the U.S. balance of trade.

In many coastal areas, however, good environmental conditions are threatened by point and nonpoint sources of pollution. Thirty-five percent of estuarine waters assessed in the U.S. are impaired and 10% are threatened. Runoff from diffuse sources like city streets, farms, suburban lawns, and forest clear cuts contribute significantly to the problem. The environmental and economic consequences of coastal water pollution are serious. In 1992, for example, beaches were closed or advisories issued against swimming on almost 3,000 occasions.[28] This is an underestimate of the problem because not all states monitor beach quality; only four states monitor the entire length of their shoreline. Beach closures can have a devastating effect on local economies.

Intensive residential and commercial development of coastal areas, particularly fragile, storm-prone areas such as barrier islands, puts life and property at risk and creates substantial financial liabilities. For example, there are currently an estimated 276,000 households located in high-hazard areas threatened by storm surge, and an additional 2.4 million households located in the floodplain adjacent to this high-impact zone. In addition, between 1970 and 1989, 46% of all new construction and 40% of commercial and industrial construction occurred in coastal counties.[29] Coastal storms such as hurricanes annually cause billions of dollars of damage. For example, damages from Hurricane Hugo in South Carolina in September 1989 totalled $10 billion. Some damages from coastal storms could be avoided by making better decisions about placement of development in coastal areas.

American businesses rely on modern, efficient seaports for export and import of many products. However, sites for the future disposal of dredged material necessary to keep these ports open are limited or conflict with other potential uses, including conservation. Older urban waterfronts are in decline in many cities, and thoughtful planning and the revitalization of these areas is essential for their future economic viability.

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[26] *Florida Keys National Marine Sanctuary Draft Management Plan/Environmental Impact Statement* (U.S. DoC, NOAA, National Ocean Service, Sanctuaries and Reserves Division, March 1995).

[27] Dalton, D., S. LaPorte, and H. Marano, *International Travel and Tourism - A Source of U.S. Economic Strength* (U.S. DoC, Economics and Statistics Administration, June 1995).

[28] Weiant, P., *Testing the Waters IV: The Unsolved Problem of U.S. Beach Pollution* (Natural Resources Defense Council, New York, August 1994).

[29] Cullitan, T.J., et al., *Building Permits Along America's Coasts: 20 Years of Building Permits, 1970-1989* (U.S. DoC, NOAA, National Ocean Service, August 1992).

Numerous activities take place in ocean waters off the coast, some of which come into conflict with one another. The management of competing uses such as fishing, marine transportation, oil and gas development, recreational boating, and whale watching poses a challenge to protection of coastal ecosystems. Currently, the management structure to resolve such competing uses is generally fragmented and regulatory-based. New comprehensive national and regional planning efforts are required to achieve a more effective governance regime for these multiple and sometimes conflicting uses of the oceans.

The health and productivity of coastal ecosystems depend on a complex array of biological and physical processes functioning at a wide range of geographic and temporal scales. This range of scales and complexity of interactions make it difficult to make accurate predictions and effective management decisions for conservation and sustainable development of coastal resources. Lack of information about the causes and consequences of multiple stresses further complicates management decisions. Improved understanding of coastal ecosystems at appropriate geographic scales and design of successful coastal management solutions is critical to sustaining healthy coasts.

SUMMARY OF OBJECTIVES

NOAA will position itself to act effectively as one of the primary stewards for the Nation's coastal resources and as a leader in coastal stewardship efforts worldwide. The challenge is to make maximum use of limited financial resources, available information, and shared management authority among many decisionmakers. NOAA will take a leadership role to sustain healthy coasts by working towards three objectives:

- Protect, conserve, and restore coastal habitats and their biodiversity.
- Promote clean coastal waters to sustain living marine resources and ensure safe recreation, healthy seafood, and economic vitality.
- Foster well-planned and revitalized coastal communities that sustain coastal economies, are compatible with the natural environment, minimize the risks from natural hazards, and provide access to coastal resources for the public's use and enjoyment.

These three related objectives comprise the elements of a healthy coast. Moreover, the interaction between living resources, habitat, water quality, and human activity are recognized, though not fully understood, especially at regional or ecosystem scales. This Sustain Healthy Coasts plan is NOAA's strategy to understand the interaction and design and implement effective management solutions, in partnership with other Federal, tribal, state, territorial, and local government agencies, and the private sector. Partnerships will be sought with countries and regions where cooperative efforts are necessary to effectively address problems facing shared coastal ecosystems.

Objective 1. ***Protect, conserve, and restore coastal habitats and their biodiversity.***

To improve stewardship of coastal habitats and biodiversity, NOAA will increase its efforts to identify and assess habitat requirements of key species, build the capability to use biodiversity as an indicator of coastal health, and better understand habitat function, threats, and the consequences of change to living resources. NOAA and its partners will use this information to implement and enhance protection, damage assessment, and restoration solutions to problems threatening living marine resources and the habitats that sustain them.

The stewardship of coastal ecosystems calls for scientific understanding and management strategies that often cross local, state, and national boundaries. While resource-specific and site-specific assessments are common on both the local and regional levels, the national capability to integrate this information to better understand cumulative effects and larger ecological and social systems is limited. Addressing this problem requires resource planners and managers at all levels of government to have the best available information on the abundance, distribution, and condition of our natural resources; the value of these resources in ecological, social, and economic terms; and an indication of future trends and conditions given various management and policy decisions. NOAA will work closely with its regional, state, and local partners to develop and implement science-based regional approaches to better manage natural resource systems at the appropriate spatial and temporal scales.

Objective 2. ***Promote clean coastal waters to sustain living marine resources and to ensure safe recreation, healthy seafood, and economic vitality.***

To promote clean coastal waters, NOAA must increase decisionmakers' understanding of factors that affect water quality and how water quality affects ecosystem functions. NOAA, working with the U.S. Environmental Protection Agency (EPA), will conduct research on the transport, fate, and effects of contaminants, nutrients, and other pollutants. NOAA also will monitor and assess changes in coastal water quality. NOAA will work with EPA, state, and local governments to implement solutions to coastal pollution problems, particularly for nonpoint source pollution. NOAA will inform the public and coastal decisionmakers about the problems and the best possible solutions.

Objective 3. ***Foster well-planned and revitalized coastal communities that are compatible with the natural environment, minimize the risks from natural hazards, and provide access to coastal resources for the public's use and enjoyment.***

A healthy coast is essential to a strong economy and better quality of life. To foster sustainable coastal communities and conserve coastal resources, NOAA and its partners in Federal, state, territorial, tribal, and local government must better understand the physical processes and cumulative impacts of development affecting coastal shorelines and the economic value of coastal resources and recreational activities. NOAA and its partners will conduct research on coastal processes (e.g., beach and bluff erosion) and NOAA will assess

the value of coastal resources and economies. NOAA's partners in coastal states, territories, and local governments need this information to achieve well-planned development and redevelopment through improved project reviews; to enhance public access and recreational opportunities in coastal states and protected areas; and to support appropriate economic development. NOAA will make the information and solutions available to the public and coastal decision makers in a useable and timely fashion.

BENEFITS

SUPPORT OF NATIONAL GOALS

Numerous Administration policy and research efforts confirm the critical need for this Sustain Healthy Coasts initiative. Sustain Healthy Coasts directly supports the environmental research and development priorities of the National Science and Technology Council and the Department of Commerce mission to ensure and enhance sustainable economic opportunities for all Americans by working in partnership with businesses, communities, and workers. NOAA efforts to advance watershed and regional approaches to coastal resource management will provide significant contributions in an area identified as a top priority for further work by the Council on Environmental Quality, the General Accounting Office, the President's Council on Sustainable Development, the National Performance Review, and the National Research Council.

BENEFITS TO THE NATION

The Nation's economic prosperity is closely linked to the ecological and economic health of the coasts. Between one-third and one-half of all American jobs are located in coastal areas, and about one-third of the Nation's gross national product is produced there. Most of this commercial activity is directly or indirectly dependent on healthy coastal ecosystems. In 1994 alone, U.S. consumers spent an estimated total of $39.4 billion for fishery products, including expenditures at food service establishments, such as restaurants, carryouts, and caterers, retail sales for home consumption, and industrial fish products. By producing and marketing a variety of fishery products for domestic and foreign markets, the commercial marine fishing sector contributed $20.2 billion (in value added) to the U.S. Gross Domestic Product.[30]

NOAA's stewardship of coastal resources includes work with neighboring country, regional, Federal, state, tribal, and local partners to protect the nation's 95,000 miles of coastline bordering three oceans, two other countries, and over 5000 miles of shoreline along the Great Lakes. Effective stewardship of these coastal areas during the next decade will ensure

[30] Fisheries of the United States, August 1994, Current Fishery Statistics No. 9400 (U.S. DoC, NOAA, National Marine Fisheries Service, August 1995).

that they continue to function as an important and sustainable resource base for the Nation's economy and future generations. Full achievement of the Sustain Healthy Coasts objectives will result in:

- Healthier coastal and Great Lakes habitats for sustainable use of coastal and marine resources and improved productivity of commercial and recreational fisheries.
- Reduced risks to public health and lower cleanup costs for contaminated areas of coastal and Great Lakes waters and sediments.
- Sustained natural diversity within coastal ecosystems and potential for biotechnology applications for medicinal, industrial, and other uses.
- Development of novel industrial materials, processes, and uses of living marine resources, for new bioindustries with enhanced economic growth and international competitiveness.
- Reduced costs for property damages from coastal storms, erosion, and other hazards.
- Improved ability to assess market and non-market values of coastal resources and recover resource damage and restoration costs.
- Enhanced marine tourism, recreational opportunities, and public access to the coast.
- More informed public that will make better decisions about its use of and involvement in coastal areas.

THE STRATEGY

RELATIONSHIP TO NOAA MISSION

The NOAA mission statement challenges the agency to promote global environmental stewardship and describe and predict changes in the Earth's environment. Promoting and sustaining the health of coastal ecosystems is the cornerstone of NOAA's environmental stewardship activities and essential to sustainable economic development of the Nation's coasts. NOAA's other stewardship goals to Build Sustainable Fisheries and Recover Protected Species depend on healthy coastal ecosystems for their success. Without adequate habitat and clean coastal waters, commercial and protected species and the ecosystems on which they depend will not be sustained or restored.

The Sustain Healthy Coasts initiative is the most complex of the seven elements of NOAA's Strategic Plan. It integrates activities across six of NOAA's seven line and program offices and derives its legislative mandates from thirteen separate statutes, including the Clean Water

Act, Coastal Zone Management Act, Fish and Wildlife Coordination Act, Marine Protection, Restoration, and Sanctuaries Act.[31]

Through this initiative, NOAA has an opportunity to coordinate among these laws and their related programs and with other Federal, state, tribal, and local agencies in coastal and ocean areas to strengthen the management of coastal resources. International or bilateral partnerships also are required as coastal ecosystems often transcend national boundaries. Cooperative efforts will be necessary with neighboring countries or regions to successfully implement solutions where these resources are shared. NOAA also has a unique opportunity to make the best use of protected areas wholly or jointly managed by NOAA (e.g., marine sanctuaries and estuarine research reserves) and other protected areas (e.g., Endangered Species Act critical habitats, ecologially significant areas under the Marine Mammal Protection Act, habitat areas of particular concern and essential fish habitats under the Magnuson Fisheries Conservation and Management Act, and special management plan areas under the Coastal Zone Management Act) to improve the understanding of coastal ecosystems. These protected areas provide ideal locations for research and for testing innovative management solutions.

NOAA's strategy to reach the three objectives involves: (1) providing greater understanding of interactions among the components of healthy ecosystems; (2) designing and implementing management solutions that are comprehensive, integrated, and geographically-focused over a variety of scales; and (3) synthesizing and communicating information about coastal environmental problems and solutions to coastal decisionmakers and the public. NOAA will provide regional or place-specific information and solutions for managers as an effective and efficient means of integrating efforts across disciplines, among partners, and towards specific geographic areas.

OBJECTIVES

NOAA will use the full range of its capabilities (research, assessment, monitoring, management, technology transfer, education and outreach) to achieve each of the three objectives. The following section describes the specific actions that NOAA will take to accomplish the three objectives.

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[31] Sustain Healthy Coasts includes the following seventeen programs: National Habitat Protection Program, National Coastal Management Program, National Estuarine Research Reserve Program, National Marine Sanctuary Program, Hazardous Materials Response Program, Damage Assessment and Restoration Program, Strategic Environmental Assessments Program, National Status and Trends Program, CoastWatch Change Analysis Program, Ocean Remote Sensing Program, Environmental Research Laboratory Programs, Coastal Ocean Program, Sea Grant College Program, Regional Marine Research Program, Center for Coastal Ecosystem Health, National Undersea Research Program, and Coastal America.

Objective 1. *Protect, conserve, and restore coastal habitats and their biodiversity*

U.S. fishery stocks have been significantly affected by overfishing, but also by the loss and deterioration of coastal habitats, especially estuaries and wetlands. Landings of estuarine dependent fisheries are down, and the shellfishing industry is operating at historically low levels. Anadromous fish populations (e.g., salmon in the Pacific Northwest) have declined significally and the genetic diversity of many populations is very low, increasing the probability of disease and extinction. Loss of habitat and the subsequent impacts on fishery resources not only mean fewer jobs for the fishermen, processors and vendors, but also declines in recreational fisheries and their associated economic activity that is vital to coastal communities and their economies.

Wetlands, estuaries, coral reefs, and other coastal habitats are essential resources for many other species as well. Migratory birds, marine mammals, sea turtles and some of the most diverse collections of species anywhere on the planet depend on healthy coastal habitats and good water quality for survival. These habitats have ecological and economic significance. Wetlands, for example, play significant roles in maintaining water quality, retarding erosion, retaining flood waters, filtering contaminants, and providing opportunities for tourism and recreation.

Coral reefs, like tropical forests, are biologically diverse and a potentially important source of new biochemical products. Coral reefs are also very fragile and thus extremely sensitive and susceptible to physical destruction and environmental stress such as water pollution, siltation, and increased water temperature. Human and natural stresses have already greatly affected the health of coral reef systems worldwide, making them one of the top stewardship priorities in the U.S., including the U.S. territories and commonwealths.

While the threats to a discrete coastal resource can be partially addressed by accurately identifying, conducting research on, and managing the resource (e.g., single wetland, coral reef), the general health of coastal resources is still eroding using conventional short-term, small-scale management approaches. Effective coastal stewardship requires a better understanding of the cumulative effects of multiple stresses and the appropriate management of those stresses. This is particularly true of interactions at larger scales, such as regions or ecosystems, where information has been unavailable. To achieve this objective, NOAA will conduct research and support management at the appropriate geographic scales to ensure the long-term health of coastal ecosystems.

Understand the Problem

NOAA currently conducts research on coastal habitats and biodiversity to understand how they function to support populations of valued living marine resources such as marine fisheries. NOAA also conducts research to quantify and predict undesirable effects on habitats and biodiversity, to develops new methods of restoration following damages, and to

define and measure indices of habitat condition (e.g., physical, geological, biological) and coastal ecosystem health (e.g., biodiversity).

NOAA uses a variety of methods, from systematics to experimental approaches, to describe and understand habitats and biodiversity, and then develop technologies to better fulfill mandates for protection, conservation, and restoration of these precious resources. Many of the research activities are coordinated and conducted out of science centers, environmental research laboratories, marine sanctuaries, and estuarine research reserves. In addition, NOAA currently provides satellite remote sensing and in situ environmental data and information for the coastal U.S. and the Great Lakes.

NOAA will focus additional efforts to better understand habitat and biodiversity problems in the three priority areas described below:

1. Identify and monitor habitats and biodiversity

The success of management decisions is often determined by the information available. Information on the quality, quantity, and distribution of coastal habitats and biodiversity is essential for effective and efficient resource management. To provide this important information NOAA will:

- Identify essential habitats for fish and other living marine resources.
- Define and assess habitats with special efforts to identify regional habitat requirements, preferences, and usage patterns for key species.
- Inventory and monitor coastal biodiversity, particularly in protected areas (e.g., marine sanctuaries and estuarine reserves) to enhance NOAA's ability to use changes in biodiversity as an indicator of habitat quality and coastal ecosystem health, where appropriate.

2. Understand how habitats function, the role of biodiversity, potential threats, and the consequences of change

NOAA will conduct research on the role of habitats and biodiversity in supporting living marine resources. These studies will focus on determining the effects of specific human activities on fisheries and other coastal resources (e.g., causes of coral reef degradation, coastal wetland loss, changes in freshwater flows into estuaries) and contribute to the large-scale, regional studies described in the next section. NOAA will undertake the following activities and make the results available to coastal decisionmakers:

- Pursue long-term research and monitoring efforts to document short- and long-term changes in habitat characteristics, structure, and function in response to natural and anthropogenic factors.

- Work to determine how multiple contaminants affect living marine resource health and productivity.

- Develop better capabilities to assess and predict the cumulative impact of land uses and management actions on coastal ecosystem health and fisheries productivity.

- Increase understanding of the role of biodiversity in coastal habitat and ecosystem function to better predict and manage changes in biodiversity.

- Identify life cycles and ecological effects of nonindigenous species.

- Conduct and support research to identify key species and communities that control habitat productivity and composition, and affect the flux of materials within and through the ecosystem.

- Increase understanding of the linkages within and between biotic components and coastal habitats.

3. Develop regional scale understanding of ecosystem processes and cumulative effects of multiple stressors.

NOAA, in cooperation with local, state, regional, and international partners, will conduct regional studies of the cumulative effects of major human-induced stresses on coastal ecosystems. Attention will be focused on a limited number of coastal ecosystems to demonstrate the capabilities and benefits of improving the scientific basis for broader-scale approaches to resource management. NOAA also will facilitate better coordination among Federal agencies and coastal states for the management of ocean activities affecting resources of the U.S. exclusive economic zone (EEZ). In partnership with other agencies to minimize costs and capitalize on existing information, project locations, and expertise, NOAA will:

- Expand the scope and number of regional studies to quantify trends in coastal habitats and biodiversity, understand ecosystem processes, and cumulative effects of multiple stressors.

- Assess regional changes in coastal ecosystems resulting from major threats (e.g. coastal development, diversion of freshwater flows, habitat loss, nutrient overenrichment, and toxic contaminants).

- Combine observational, experimental, and modeling approaches in field and laboratory research to understand ecosystem-level processes, broader-scale management, and assess market and nonmarket values of ecosystem functions.

- Participate in interagency efforts to understand the role of oceans in global climate change by identifying major sources of organic carbon in selected coastal ecosystems and determining how this material is used and modified by biological activity.

- Foster better coordination among Federal agencies and coastal states in the planning for and management of resources of the U.S. EEZ.

- Participate in global coral reef monitoring as part of the coastal and living resources module of the Global Ocean Observing System.

Effective monitoring on regional to global scales will require greater reliance on in situ and remote sensing observing systems. Current capabilities, and the access provided by interagency and international agreements to future satellite data streams (ocean color, synthetic aperature radar, scatterometer) will facilitate an expansion of environmental information and monitoring tools. Applications for current and future remote sensing data include quantification and identification of algal pigments, primary productivity, and harmful algal bloom detection; automated detection and tracking of physical features (fronts, eddies, current); fisheries productivity and protected species assessments; pollution monitoring and tracking; incorporation of remote sensing data into land-use impact, ecosystem, and water quality models; and wetland mapping and change detection. Calibration and validation of these data is essential to their accuracy and utility. To develop and deliver these information and monitoring tools, NOAA will:

- Develop regionally tailored algorithms to convert data to the products and information useful to resource managers.

- Develop and adapt advanced technologies to improve the temporal and spatial resolution and cost effectiveness of coastal environmental observations.

- Implement demonstration projects in the application of remote sensing to coastal science and management.

- Expand land-use change analysis using remote sensing.

Implement and Enhance Solutions

Greater understanding of the problems affecting coastal habitats will increase NOAA's ability to conduct and support management activities to protect, conserve and restore coastal habitats and their biodiversity. NOAA will focus management activities in the following four areas:

1. Protect habitat and biodiversity

The protection of coastal habitats and biodiversity can occur through the direct acquisition/ designation and management of particular sites or by influencing other management actions. NOAA will work with states, local governments, and other Federal agencies, and regional and international organizations to:

- Strengthen the coastal habitat protection components of state coastal management and protected area programs including land acquisition; land and water-use planning and zoning; wetlands mitigation; special area management planning; and coastal dependent facility siting (e.g., aquaculture, wastewater disposal, marinas).

- Improve marine and estuarine habitat protection in consultations on Federal projects and permits (e.g., review of dam relicensings and major water resource development projects for navigation, flood control, water supply, hydropower, energy development, and irrigation), and development of fishery, marine sanctuary, and estuarine reserve management plans (e.g., incorporation of specific habitat provisions mandated by Magnuson Act).

- Identify national and regional policies and seek consensus among the governmental agencies with a role in habitat protection and restoration.

- Incorporate biodiversity assessments as a specific element in fishery, marine sanctuary, and research reserve management plans.

- Improve evaluation of changes in coastal and ocean habitats for resource managers, including using coastal change analysis and other methods.

- Cooperatively develop cost-effective, environmentally sound strategies with government and industry partners to control nonindigenous species.

- Automate delivery of critical information on accidental spills of oil and hazardous materials in coastal ecosystems (e.g., spill trajectory, chemical hazard analyses, marine and estuarine habitat sensitivity, and mitigation options).

2. Restore habitat and biodiversity

Physical restoration of degraded coastal habitat is an important way to increase habitat quantity and quality. However, there is also a need to improve restoration techniques and to evaluate the success of restoration projects. To strengthen its current habitat restoration efforts, NOAA will:

- Design, implement, and provide oversight of new direct restoration projects.

- Develop, test, and implement improved habitat restoration and mitigation methodologies, including protocols for wetlands, anadromous fish streams, and offshore sites degraded by fishing activities.

- Improve strategies for evaluating habitat restoration success such as conducting baseline monitoring of previous habitat restoration projects.

- Improve ability to determine the injury to habitats and implement resource restoration and/or replacement to compensate for damaged trust resources.

- Build state capabilities to handle specific types of damage assessment and restoration through transfer of NOAA information and technology.

- Increase partnerships with non-NOAA entities (Federal agencies, state agencies, the private sector) for planning activities, joint permit processing related to large-scale and regional restoration efforts.

3. Enhance adaptive, ecosystem approaches to resource management

The complexity of coastal ecosystems necessitates that management actions be formulated at the appropriate regional, state, or local scale. To address this need, NOAA will:

- Increase its involvement in existing regional or ecosystem efforts (e.g., Chesapeake Bay, Gulf of Mexico Program, South Florida, Pacific Northwest, Prince William Sound and Kenai River, Alaska, Coastal Louisiana, Great Lakes, Gulf of Maine, Monterey Bay and Central Valley, California, National Estuary and Great Waters Programs, U.S.-Mexico border, U.S.-Canadian border, and the Caribbean and Pacific regions).

- Expand the use of regional models such as large marine sanctuaries.

- Develop science-based management tools in conjunction with regional studies, including ecosystem restoration and mitigation techniques.

- Coordinate regional approaches with regional institutions.

Inform Decisionmakers and the Public

Stewardship for coastal habitats and biodiversity requires cooperative partnerships, access to information, and an informed public. NOAA provides information and technology to its management partners and the public through field representatives, workshops, publications, and electronic media. NOAA will increase technology transfer and access to information by:

1. Transfer Information and Technology to Coastal Decisionmakers

NOAA generates useful information from its research, monitoring, assessment, and management activities. It is important that the information be made available to coastal decisionmakers in a useable form and in a timely fashion. NOAA will make use of its field staffs, partnerships with universities, state and local governments, and resource centers to transfer technology to coastal decisionmakers in the U.S. and abroad.

- Collect, synthesize, and distribute comprehensive information on coastal and ocean resource health and management, with particular attention to successful regional approaches.

- Transfer habitat restoration protocols and technology to Federal and non-Federal coastal managers for restoration of degraded wetlands, streams, and other coastal habitats (e.g., document restoration demonstration projects in sanctuaries, reserves, and other interagency priority areas).

- Increase NOAA involvement in fishery management councils and commissions, and other Federal, state, and local resource agencies, particularly to communicate NOAA science and assessment information.

- Provide state-of-the-art electronic access to data and information, as well as GIS and document syntheses that pertain to physical, chemical, and biological habitat characteristics, habitat protection, restoration, and conservation.

- Provide current and retrospective satellite remote sensing and in situ environmental data and information to resource managers and researchers.

- Solicit views of coastal managers and researchers on their information needs.

- Publish a biennial report assessing the health of the Nation's coastal ecosystems.

2. Educate decisionmakers and the public

Education of coastal decisionmakers and the public is key to informed coastal resource management.

- Provide technical training for U.S. and international coastal resource decision-makers (e.g., joint research reserve - marine sanctuary - coastal management workshops, UN organization workshops).

- Conduct workshops to share techniques of adaptive, ecosystem approaches to resource management, including the assessment and management of cumulative and secondary impacts of development, with state and local decisionmakers.

- Provide fellowships and research assistantships to highly qualified students in high priority fields (e.g., ecosystem processes, biodiversity).

- Develop public outreach programs to address emerging coastal resource science and management issues such as habitat restoration, water pollution, and biodiversity conservation in the U.S. and abroad.

- Design, implement, and assess education programs to improve K-12 coastal and marine resource education.

Objective 2. ***Promote clean coastal waters to sustain living marine resources and to ensure safe recreation, healthy seafood, and economic vitality.***

Good coastal water quality is essential to the health of coastal ecosystems. The productivity and diversity of living marine resources depend on it. Without good water quality, recreational activities like swimming and sailing become health hazards, seafood becomes unsafe for human consumption, and coastal tourism is jeopardized. To promote clean coastal waters, NOAA must understand the problems affecting water quality and their effects on coastal ecosystems and coastal communities. Given the extent and complexity of factors affecting coastal water quality, it is important to conduct research, monitoring, and assessment activities at local, watershed, and regional scales. NOAA will help develop and implement appropriate solutions to these problems, in partnership with other regional partners, Federal agencies, coastal states, territories, local governments, and interest groups. The results of these actions will be monitored and assessed. The public and coastal decisionmakers will be informed about the problems and how best to solve them.

Understand the Problem

NOAA currently conducts research on the sources, transport, fate, and effects of contaminants, nutrients, and sediment in coastal ecosystems. Specific on-going research projects include studies of sediment/water column processes, toxic cycling, and biogeochemical cycling. NOAA has also made a significant investment in research relating to the effects of toxics on living marine resources.

NOAA has joint responsibility with the EPA for national coastal monitoring. NOAA's coastal monitoring focuses on two primary areas: (1) targeted baseline monitoring of shellfish and sediment to detect changes, and (2) the identification of contaminants that degrade ecosystem health. NOAA also assesses environmental quality by using satellite imagery, aerial photography, in situ monitoring, and research data organized in a GIS

context. In addition, NOAA monitors the overall health of coastal waters and the success of water quality protection and restoration efforts at specific sites such as estuarine research reserves. NOAA is an important provider of this information to other Federal, state, territorial, and local resource management agencies.

NOAA provides predictive tools and capabilities to understand what happens to pollutants in coastal systems, and aids in the formulation of responses to contaminant spills. NOAA conducts real-time monitoring of physical characteristics such as circulation, water levels, salinity, and meteorological variables in a number of estuaries. Using synthetic aparature radar and ocean color satellite remote sensing, NOAA observes coastal currents at a variety of scales important for detecting, tracking, and responding to oil spills; observing ocean outfall discharges; and observing other chronic and acute pollution events. NOAA has worked to determine the mechanics of effluent discharge plume dilution and dispersion and is developing additional remote sensing techniques to monitor the presence of contaminants in coastal waters. NOAA and its partners use this and other information to develop and employ models to better understand circulation patterns and water quality, and their interactions with habitats and larval transport.

NOAA will advance the understanding of coastal pollution and its effects to ecosystems through research, assessment, and monitoring activities. The success of various management actions will be evaluated through NOAA and coastal state monitoring programs.

1. Conduct water quality research and assessment

Understanding how water pollution affects coastal ecosystems is key to designing monitoring programs and management solutions. To advance this understanding, NOAA will:

- Conduct and support research to understand the processes that determine transport, cycling, fate, and effects of contaminants and nutrients in coastal and Great Lakes ecosystems.

- Conduct research to examine the interactions and ecosystem impacts of multiple stressors, such as interactions between multiple contaminants, contaminant mixes, toxic pollutants, and nutrients, or interactions between habitat modification and pollution.

- Examine the natural and anthropogenic factors that control the development of water quality problems such as harmful algal blooms and toxic chemical impacts on living marine resources.

- Conduct research on atmospheric transport processes that deliver contaminants to coastal watersheds over a range of distances.

- Evaluate the offshore effects of land-based contaminants and nutrients.

- Compare highly, moderately, and relatively unstressed watersheds to determine effective and efficient indicators and management strategies.

- Establish the scientific foundation for decisionmaking and integrated planning for shared ecosystems like the U.S.-Mexico Tijuana River watershed.

- Establish a North American Quality Assurance Program for aquatic and atmospheric chemical measurements to assess compliance with common environmental standards.

2. Enhance water quality monitoring

Improved coastal water quality monitoring will assist coastal decisionmakers in designing and implementing solutions to coastal water pollution. To improve coastal water quality monitoring NOAA will:

- Improve the capabilities to monitor pollutants from nonpoint sources (e.g., nutrients and sediment) and determine the effects on coastal ecosystems.

- Continue to evaluate remote sensing technology for use in monitoring and predicting coastal water quality characteristics, including retrospective analysis of long-term data.

- Develop better methods and indicators to measure coastal water quality, including methods for local government or volunteer-based water quality monitoring.

NOAA's coastal research is currently supported by two vessels -- the McARTHUR and the FERREL -- and supplemented with contracts and use of UNOLS vessels. Ship platforms are key to the collection of essential status and trends data on the health of the coastal zone. Over the long-term, NOAA's coastal data collection efforts are envisioned to be met through charters and the use of UNOLS or university research vessels.

Implement and Enhance Solutions

NOAA is responsible for developing and implementing solutions to coastal water quality problems, in many cases in partnership with other Federal and state agencies. NOAA and EPA jointly oversee the development and implementation of management measures for the control of nonpoint source pollution from numerous sources. In addition, NOAA and its state partners work with landowners in the watersheds of estuarine research reserves to protect and improve water quality in reserves. NOAA also develops and implements water quality protection plans in marine sanctuaries where it has direct management responsibility for the resources. Plans currently are being developed for the Florida Keys and Monterey Bay National Marine Sanctuaries.

NOAA also develops and implements techniques to assess and restore resources damaged by oil spills and chemical releases. NOAA anticipates transferring this natural resource assessment and restoration capability to states for many of the smaller cases beyond the scope of the national program. NOAA also develops environmental technologies to: (1) reduce or eliminate pollutant discharges from seafood processing and aquaculture facility waste streams, and (2) restore or remediate contaminated Great Lakes and coastal waters and sediments.

NOAA reviews and comments on Federal, state, local, and private actions that could affect coastal water quality. Through its review of proposals for ocean dumping, port and harbor dredging, and major wetlands fills, NOAA provides comments on the projects and suggestions on how to minimize and mitigate for impacts. To enhance coastal water quality, NOAA will:

1. Improve water quality assessment and management techniques

Developing better techniques for assessing and managing water quality impacts is an important step towards improving Federal, state, and local decisions affecting water quality. NOAA will contribute expertise in the following ways:

- Develop multi-scenario waste allocation models and best management practices for managing point and nonpoint source pollution.

- Develop technologies to reduce or eliminate pollutant discharges in waste streams of coastal industries (e.g., aquaculture).

- Synthesize information and techniques to assessing and managing the cumulative and secondary impacts of coastal development on water quality and make the information available to state and local government decisionmakers..

- Transfer natural resource damage assessment and restoration capability to coastal states for specific cases.

2. Enhance governmental decisions and implement water pollution controls

Improvements to coastal water quality requires changes in the way activities affecting coastal waters are conducted. NOAA will improve the management of these impacts directly where it has clear responsibility for the resources (e.g., protected areas), and indirectly through partnerships with other Federal, state, and local government agencies.

- Accelerate development and implementaton of water quality protection plans for marine sanctuaries.

- Expand efforts with landowners in the watershed to protect and improve water quality within estuarine research reserves.

- In cooperation with EPA, assist coastal states in developing programs to implement management measures for nonpoint source pollution control.

- Increase NOAA consultations with state, local, and Federal agencies on decisions affecting water quality where there are high risks to living marine resources.

- Increase participation in ecosystem and watershed interagency partnerships for total water quality management (e.g., Chesapeake Bay and South Florida).

- Participate in the design of a global program of action to deal with land based sources of marine degradation.

- Conduct hazardous materials response and assessment activities, including international technical assistance and technology transfer, in support of U.S. treaty commitments, promotion of U.S. environmental technologies exports, and U.S. humanitarian efforts.

Inform Decisionmakers and the Public

NOAA provides information about coastal water quality problems and solutions to coastal decisionmakers through synthesis of existing information, techniques, and policies; technology transfer; and training. For example, NOAA has initiatied several projects to demonstrate the best available technologies for nonpoint source pollution control. NOAA using various means provides information to the public. Public service announcements, videos, publications, and workshops are some of the primary tools for public outreach on water quality issues.

To enhance the delivery of water quality information to coastal decisionmakers and the public, NOAA will:

- Implement a national training program for federal, state, and local coastal resource managers on solutions to water quality problems.

- Develop and disseminate information on best available management measures for nonpoint source pollution control and ways to implement them at state and local levels.

- Develop workshops that teach integrated watershed/ecosystem management techniques to state, local, and international decisionmakers.

- Conduct national workshops on the assessment and management of cumulative and secondary impacts of development on coastal water quality.

- Sharpen the focus of public education and outreach efforts to deliver information to the public on coastal water quality problems and solutions.

- Develop better means to share coastal water quality information with decisionmakers in state and local government.

Objective 3. ***Foster well-planned and revitalized coastal communities that sustain coastal economies, are compatible with the natural environment, minimize the risks from natural hazards, and provide access to coastal resources for the public's use and enjoyment.***

A wide range of economic activities occurs along the coast, including, tourism, shipping, fishing, oil and gas production, and services for coastal residents. Every coastal community is different with some experiencing intense new development, and others seeking to revitalize derelict waterfront areas and replace declining industries with new economic opportunities. The challenge is to balance competing priorities while fostering economic health and environmental health.

One of the keys to economic and environmental health for coastal communities is careful planning for development or redevelopment. As discussed in the previous two objectives, maintaining the health of economically important resources like fisheries and clean swimming beaches is critical. It is essential that state and particularly local decisionmakers have good information about the importance of coastal resources to their economies. It is also important for them to have information on the latest land-use planning techniques and the legal issues that surround land-use planning. In addition, coastal areas are prone to threats from storms, hurricanes, typhoons, tsunamis, and coastal erosion and flooding. Losses of life and property from coastal storms are greatly affected by how well communities have planned for such hazards. In short, the health of coastal economies and the lifesyles they afford depend on well-planned, sustainable development and healthy coastal resources.

To achieve sustainable coastal communities and conserve coastal resources, NOAA must: (1) better understand the physical processes affecting coastal areas and development, and the economic value of coastal resources and recreational activities; (2) work with its partners in coastal states to foster well-planned development and redevelopment; and (3) make the information and solutions available to the public and coastal decisionmakers in a useable and timely fashion.

Understand the Problem

State and local coastal officials need good information on which to base decisions about coastal development. Two areas in which NOAA can advance the state of knowledge is: (1) to develop new methods for determining the value of coastal resources to local economies, and (2) to improve data and information about coastal erosion and sea level rise.

1. Assess the value of coastal resources and economies

Coastal population growth and development will increase the stress on coastal ecosystems. Decisions will be made by industrial, land development, and regional, Federal, state, and local coastal managers that will have significant economic and ecological implications. Decisionmakers need accurate, complete information on the value of coastal resources and the costs of various actions. Scientists, economists, and resource specialists must work together to provide estimates of environmental value. These estimates will be included in calculating the costs and benefits of proposed actions.

NOAA has economists who have worked on the economic valuation of coastal resources for damage assessment and other purposes. NOAA will enhance these efforts by developing new methods to value the contribution of healthy resources to coastal economies. NOAA will:

- Develop predictive models that produce testable forecasts of coastal development and coastal ecosystem health.
- Evaluate the methods that place a monetary value on coastal ecosystems, as well as the methods that attempt to quantify habitat functions.
- Investigate the basis of equivalent currencies for describing the resources available in coastal ecosystems, including commercial and subsistence fishing, ecological function of habitats, recreational uses, ports, harbors, marinas, and others.
- Enhance the ability to place aesthetic and existence values on coastal ecosystems, particularly where recreational and developmental interests compete for their use.
- Work with coastal communities to identify the costs and benefits of economic activities such as tourism and waterfront redevelopment.
- Understand the economic and community values associated with the use and preservation of marine resources and coastal environmental assets.

2. Assess and evaluate coastal hazards and development

Coastal storms and chronic erosion affect millions of dollars of development each year. Structures built in coastal areas can exacerbate erosion by altering the movement of sand. Better understanding of coastal processes and the future effects of sea level rise is essential to minimizing the long-term loss of life and property. NOAA works with other Federal agencies (e.g., Federal Emergency Management Agency) and state and local government officials and counterparts in other nations to collect and provide data and information about coastal erosion and sea level rise. NOAA also provides long-term coastal data and

information related to coastal development and economic impacts, and seaport water level and mid-range coastal forecasts.

To enhance these efforts NOAA, in cooperation with its regional, binational, and state partners, will:

- Support additional studies of the physical processes affecting important coastal and Great Lakes shorelines and features.
- Assess the physical, biological, and social impacts of natural disasters and human-caused problems.
- Develop methods to evaluate the economic costs of storm damage and recovery.

Implement and Enhance Solutions

State and local governments can benefit from learning about successful development planning and management techniques from other areas, including the international community. They can also improve the resolution of conflicts among competing uses by engaging in planning for the full range of uses in a discrete area (i.e., special area management planning).

1. Promote well-planned coastal development and redevelopment

NOAA works with its state, regional, and territorial coastal management partners to manage all aspects of coastal development and redevelopment, including coastal hazard mitigation, public access, urban waterfront revitalization, harbor management, and coastal resource protection. NOAA also manages the resources within special protected areas to the benefit of local economies.

To improve state and local capabilities to manage coastal development and to enhance coastal economies, NOAA will:

- Develop alternative approaches to disaster management in local communities and evaluate alternative policies (e.g., building codes, legal provisions, economic incentives) to assist state and local decisionmakers.
- Develop and disseminate information about acquiring and developing opportunities for public access to the coast.
- Conduct national workshops and training on waterfront revitalization and redevelopment.

- Support special area management plans to resolve resource use conflicts in distinct coastal areas.

- Synthesize information on the current legal issues and decisions affecting land-use planning and coastal and ocean resource management.

- Manage marine sanctuaries and estuarine research reserves to sustain and enhance the resources that contribute to the local economies.

2. Support coastal businesses

NOAA works with local businesses to develop new technologies and markets for products, particularly in the areas of aquaculture, tourism, and recreation. To further support environmentally sound economic development, NOAA will:

- Assist businesses and coastal communities in evaluating the tourism potential of recreational, historic, aesthetic, ecological, and cultural features.

- Identify likely technologies, conduct market analyses, and bring business people and entrepreneurs together to evaluate the commercial potential and support environmentally sound coastal businesses.

- Assist in the development of new products and approaches for commercial processing by the pharmaceutical, chemical, and seafood industries.

Inform Decisionmakers and the Public

NOAA provides information to coastal decisionmakers on the problems and solutions associated with coastal development and the ways to support sustainable coastal communities. NOAA also has extensive outreach to the public through its partnerships with international and regional organizations, coastal states, universities, and through programs at marine sanctuaries and estuarine reserves. To enhance these efforts, NOAA will:

- Synthesize and distribute information and conduct workshops for coastal states and local governments on such topics as: coastal hazards management, harbor management, special area management planning, public access, and waterfront revitalization.

- Develop and distribute information needed by NOAA and its partners to make decisions to sustain ecosystem health and economic prosperity in coastal areas.

- Enhance public involvement in sustaining vital coastal communities through beach cleanups and other volunteer efforts.

- Conduct forums to obtain the views and better understand the needs of the public, user groups, and government agencies associated with coastal development.

CONCLUSION

The economic engine powering the Nation's economy is fueled in large part by the unique resources of our coasts and oceans. NOAA has leveraged its capabilities through effective local, state, regional, and international, and other partnerships to ensure the health and productivity of coastal ecosystems for current and future generations. NOAA has developed world-class capabilities in coastal and ocean sciences including habitat protection and restoration; assessment and prediction of resource trends; monitoring of resources using remote sensing and other technology; and promotion of sustainable coastal resources and economies through effective management. This plan is a blueprint for future action. By focusing on the three specific objectives of protecting habitats and biodiversity, promoting clean coastal waters, and fostering well-planned coastal communities, NOAA will provide the components and synthesis of science and management for solutions to global coastal stewardship challenges in the 21st century.

NATIONAL CAPABILITIES

AND SUPPORTING INFRASTRUCTURE

RESEARCH

OVERVIEW

Information about the environment is crucial to Americans today, and they turn to NOAA with questions on an increasing number of issues. Today's society expects sophisticated assessments of environmental conditions, routinely available, for incorporation into daily personal, business, and community decisions. Many of these decisions involve substantial economic or public safety concerns. For example, local and national emergency managers rely on NOAA for severe weather and flood warnings. The aviation industry depends on NOAA global forecasts for daily routing decisions. Fisheries managers base their plans on NOAA assessments of fish stocks. Marine transport services expect modern charts and marine forecast systems.

Research constitutes the fundamental underpinning of these environmental products and services. Essentially all of the agency's national mandates and Strategic Plan goals require input from scientific investigations. The vision motivating NOAA's research is:

To provide the nation with a robust research and technical foundation in oceanic and atmospheric sciences, so that society, now and in the future, can base decisions involving or affected by these environments upon continually improving knowledge, understanding, and predictive capabilities.

The oceanic and atmospheric sciences included in the vision are diverse. Oceanic research includes physical, chemical, biological, and geological studies focused on both the open ocean and coastal environments, including the Great Lakes. Its applications include immediate needs, such as fisheries management and coastal zone planning, and long-term needs such as understanding the oceans' role in climate variability. Understanding and forecasting atmospheric phenomena, on time scales from hours to centuries, require research in weather, climate, hydrology, and solar-terrestrial disciplines. Continuity in the research enterprise is crucial: just as NOAA's present operations are built on the scientific work of past decades, tomorrow's NOAA will depend on today's research.

To fulfill its vision, NOAA sponsors both internal and extramural research programs, and leverages the research conducted by other segments of the nation's academic, industrial, and governmental research infrastructure. NOAA's science activities have three principal objectives:

- To ensure continuity of, and needed improvement to, existing services
- To synthesize scientific and technical data in support of applications, management, and policy

- To address emerging national environmental prediction and stewardship issues, and prepare the agency to meet future requirements.

CAPABILITIES

NOAA's research capability resides in its people and facilities, and in those of its academic research partners. It builds on a broad, deep base of fundamental science and advanced technology, developed both internally and under the auspices of other Federal agencies (principally NSF, NASA, and DOD). From this base, NOAA tailors its research and applications to the synthesis and assessment needed to support both its mandated responsibilities and its numerous external customers. NOAA's charter and history have given this research enterprise singular characteristics in relation to academia and other federal science and environmental agencies. A central difference is NOAA's responsibility to integrate observations, modeling, and knowledge of processes, to provide forecasts of atmospheric and oceanic conditions and living marine resources.

NOAA LABORATORY SYSTEMS

Environmental Research Laboratories (ERL)

The ERL system supports and improves NOAA's environmental prediction and stewardship services through an integrated program of research and technology development. The ERL system and associated cooperative institutes include about 1500 scientific and support personnel at 11 major laboratories located throughout the United States. Of these, about 40% are university and contract employees. Each laboratory concentrates on a particular suite of technical capabilities and/or environmental phenomena relevant to better understanding of the Earth's oceans, the Great Lakes, the lower and upper atmosphere, or the space environment (Table 1). Changes in research focus (and name) have occurred over time as individual laboratories have adjusted their efforts to changing agency needs and important emerging scientific issues and opportunities.

Fisheries Science Centers

Research at NOAA's Fisheries Science Centers provides resource managers in NOAA and other agencies with the scientific basis for informed marine fisheries management decisions. The five regional Centers (Table 2), composed of about 30 facilities nationwide and over 1500 scientific personnel, conduct a comprehensive, interdisciplinary fisheries science program. The scope of their work is broad in time, space, and discipline. Their activities include the collection of harvesting statistics and associated economic data, resource surveys, biological and ecological studies, technology development, and assessments and models of the impacts and benefits of alternative stewardship decisions. The Fisheries Science Centers work in cooperation with other federal and state agencies, academia, and the private sector, including the fishing industry.

OTHER NOAA RESEARCH COMPONENTS

NESDIS Office of Research and Applications (ORA)

ORA conducts a broad program of satellite remote sensing research, centered at the Satellite Applications Laboratory and Satellite Research Laboratory in Suitland, MD. Key areas of emphasis are the development of algorithms for deriving geophysical variables from satellite observations, monitoring instrument calibration, validating satellite products, and demonstrating new applications. A present area of emphasis for ORA is the coordination and strengthening of NOAA's satellite oceanography capabilities. Cooperative arrangements with academia are a vital component of all ORA work.

National Weather Service/Development Division

NWS scientists participate in collaborative applied research activities with scientists from NOAA's research laboratories, universities, other government agencies, and the international community. They adapt research results for direct application to the weather service mission and conduct in-house development essential to unique mission activities. The National Centers' Development Division improves numerical weather prediction and marine and climate modeling through a broad program of research in data assimilation and modeling. The Office of Hydrology develops models and data analysis methods for tracking and forecasting river and reservoir levels. The Office of Systems Development develops systems and techniques for supporting the operations of NWS field offices.

National Ocean Service

NOAA's National Ocean Service (NOS) conducts operational and applied research in oceanography and geophysics, including geodesy and the allied fields of radioastronomy and computer science. NOS formulates and executes programs in technological development and applications to geoscience programs in earth orientation, geodetic positioning, satellite geodesy, and marine geophysics. These programs have been instrumental in improving maritime navigation safety, enhancing maritime commerce, and establishing the scientific rationale necessary to make informed decisions about the land and oceans and their uses.

COOPERATIVE AND JOINT ACADEMIC INSTITUTES

NOAA's nine joint and cooperative institutes provide an invaluable augmentation of the agency's research capabilities. NOAA establishes these formal collaborative agreements with selected universities that have leading research strengths in fields of crucial, long-term importance to the agency. They provide the university with more direct access to NOAA technology and research challenges, while providing the agency with top caliber research talent in a variety of disciplines. Each joint agreement focuses on particular research areas (Table 3). Many of these institutes are recognized as national centers of excellence in these

fields. The joint institutes have played a crucial role in research of great value to NOAA's missions, for example, the design of the Tropical Atmosphere Ocean (TAO) array which has been central to NOAA's seasonal to interannual prediction capability. The typically close relationships of the academic institutions with local governments and businesses also provide effective pathways for transfer of NOAA-sponsored technology to the private sector.

PARTNERSHIP RESEARCH PROGRAMS

Office of Global Programs (OGP)

NOAA's OGP develops and coordinates national and international research programs aimed at those components of the U.S. Global Change Research Program (USGCRP) that are of top priority and of most relevance to NOAA's missions. These collaborative scientific efforts have proven extremely effective in advancing the nation's capability to predict seasonal climate variations up to one year in advance. The program awards competitive, peer-reviewed grants to academic and NOAA researchers, which fosters cross-agency and internal-external linkages.

Coastal Ocean Program (COP)

NOAA's COP develops and supports research activities to improve the understanding of coastal processes and management of coastal resources. Under this program, government and academic research partners jointly develop research plans and priorities. COP then funds the recommended research through competitive, peer-reviewed grants to both academic and internal scientists. The program pursues three main research foci: coastal fisheries ecosystems, coastal environmental quality, and coastal hazards. COP research is applicable to a broad range of NOAA's missions, as well as those of other federal agencies. By focusing on the coast, COP builds a consensus for identifying, prioritizing, and carrying out common research needs to accomplish the agencies' goals.

ACADEMIC RESEARCH PROGRAMS

National Sea Grant College Program (NSGCP)

The NSGCP is an important partnership of the federal government, state governments, and the private sector, combining university-based research, education, and technology transfer. The program comprises a network of over 300 institutions nationwide, operating through a core leadership of 29 Sea Grant Colleges and Institutions (Table 4). Through Sea Grant, NOAA can access academic expertise throughout the nation and support public outreach and education efforts. The Sea Grant program awards competitive, peer-reviewed grants to academic researchers to address urgent environmental and economic problems faced by the public, industry, and government in coastal and Great Lakes states. Sea Grant is mandated

to carry out research needed to solve coastal problems or to develop new commercial opportunities while protecting coastal resources.

Sea Grant leverages federal funding by requiring at least a 50% match by states and by encouraging partnerships with industry. It is notable for its outreach program, which fosters communication to NOAA of local and regional research needs, commercialization of new technologies, and transfer of research into effective resource management. Sea Grant has made significant contributions to countless issues of importance to NOAA and to coastal communities, in fields ranging from reduction of fisheries bycatch to improving hurricane preparedness. Three notable areas in which Sea Grant provides national coordination of efforts, as well as support, are aquaculture, marine biotechnology, and marine policy.

National Undersea Research Program (NURP)

The NURP provides access for the U.S. research community to civilian, military, and international undersea platforms. The research it supports relies upon submersibles, underwater laboratories, and diving to enable scientists to perform in situ studies, and on remotely operated vehicles and observatories for indirect access. In FY 1996, the program is directed by a national office and carried out by six university-based National Undersea Research Centers (Table 5). Primary research emphases in NURP are fisheries, coastal processes, ecosystem health, marine lithospheric processes, undersea technology, and diving safety and physiology. The program serves as a center for federal research support of the nation's coral reef resources.

CURRENT EFFORTS

OVERVIEW

NOAA today invests about a quarter of its annual budget in scientific research. Most of the investment supports scientific observations, analyses and forecasts to ensure that the national objectives under NOAA's aegis are continually supported by sound scientific data, and that the products and services NOAA provides daily to the public are accurate and reliable. Substantial effort is also devoted to synthesizing and analyzing scientific data to assist resource managers and policy makers, such as fisheries management councils, coastal zone managers, and air and water quality authorities. A smaller proportion supports selected studies of a more fundamental nature, supporting applied work by filling in gaps in understanding, providing measurements against which to test models and hypotheses, and developing new capabilities and techniques.

Atmospheric and oceanic research is a crucial link enabling the agency to carry out its mission. The agency's research strategy has three components:

• Leverage	Aggressively exploit the research capabilities and results of academia, other federal agencies, and the international community.
• Integration	Emphasize integration, synthesis and assessment of scientific data and information tailored to the needs of customers both inside and outside NOAA.
• Predictive Skill	Aggressively pursue the development and integration of observing networks, models, and research needed to predict oceanic and atmospheric change and understand processes controlling marine ecosystems.

CURRENT PROGRAM ELEMENTS: ENVIRONMENTAL STEWARDSHIP

Overview

NOAA is the steward of the Nation's marine and coastal resources. With over half of the total U.S. population living in coastal counties, pressures on the highly productive coastal marine ecosystems are great and increasing. Unconstrained fishing, degradation of the marine environment through pollution and habitat alteration, and rapidly increasing recreational and other uses have combined with natural variability to put many areas in peril. Coordinated management strategies are needed, based upon integrated research into complex physical and ecosystem interactions. NOAA's objective in conducting and sponsoring marine and coastal research is to provide the understanding and predictive tools needed to manage and sustain resources.

Build Sustainable Fisheries

NOAA is a world leader in fisheries research. Informed fisheries management decisions depend on the National Marine Fisheries Service's time series and analysis of fish population data. Each year, NOAA uses harvesting and survey data to assess the status and trends of more than 231 commercially valuable fish, shellfish and crustaceans. To improve data collection and analysis, NOAA and its collaborators are developing new observational technologies, a new nationwide computerized statistical system, and more sophisticated analysis techniques.

Dwindling stocks of marine life spur new studies of fisheries and fisheries oceanography, aimed at better management of the ecosystem through better understanding of it. These are studies of the effects on fisheries of population recruitment, interactions among species, and natural or human-induced environmental variability on fisheries. NOAA is also expanding its collection and analysis of data on the value of the catch and the economic characteristics of fishing vessels to support decisions on the use of market-based regulation. These cross-

disciplinary efforts are being undertaken in cooperation with other federal and state agencies, international organizations, and academia, and are based on long-standing cooperative research in fisheries assessment.

Some research focuses on the needs of the fisheries industry, and is performed in cooperation with industry. Joint studies of harvesting methods and development of more effective fishing gear are reducing wasteful by-catch. Joint seafood science research is aimed at handling or preventing crises in microbial or chemical seafood contamination.

Recover Protected Species

For effective management of a protected species, NOAA requires information on population trends, takes and removals, critical habitat and resource requirements, social and economic implications of management alternatives, and characterization of uncertainty and risk. To gather data quickly, NOAA is experimenting with techniques such as the recently instituted observer programs. Data from this work on incidental take are contributing to plans to reduce human interactions that have reduced populations of protected species. Like colleagues in fisheries research, these scientists are also trying to combine their studies with oceanographic observations, so that management can be placed in an ecosystem framework.

NOAA also makes a modest yearly investment to apply technological advances in other fields to protected species research. For example, at several of NOAA's Fisheries Laboratories, researchers are adapting recent advances in genetics to NOAA's needs. Thanks to this work, genetic markers for stock identification of protected species are emerging as a significant new management tool. For stock assessment, researchers are investigating new technologies such as low frequency acoustics, lidars, and satellite radio tags for their potential to supplement and improve traditional line transit techniques.

Sustain Healthy Coasts

NOAA's coastal research efforts build on existing strengths in coastal and estuarine water quality, habitat and marine biodiversity. Cooperation in coastal monitoring and research is imperative because coastal and estuarine resources are under joint federal and state responsibility, and federal obligations are further shared by a number of federal agencies. NOAA's mandates for coastal zone management, navigation, marine sanctuaries, and protection of fisheries habitat have required the agency to develop expertise in coastal monitoring, ecosystems, and coastal forecasting. These complement the terrestrial focus of the Department of the Interior, and are useful inputs to the regulatory functions of EPA.

NOAA's national programs in water quality provide leadership in determining and evaluating the quality of, and predicting changes to, U.S. estuaries and coastal waters; compiling coastal data; and scientific support for managing coastal oil and chemical spills. NOAA also

supports geographically targeted research programs in the National Estuarine Research Reserves, the Great Lakes, and other important coastal waters.

NOAA's habitat research helps in efforts to understand and manage coastal resources. The agency's work falls into three categories: status and functioning of coastal habitats; implications of change to coastal habitat; and appropriate responses to habitat change. One major goal is to define the importance of estuaries to coastal ecosystem health and identify methodologies to guide the recovery of damaged estuarine systems. Other aims include developing biogeography techniques for coastal ecosystems, and the Coastal Change Analysis Program (C-CAP), which combines satellite images of coastal areas with in situ measurements, and distributes the results to planners.

CURRENT PROGRAM ELEMENTS: ENVIRONMENTAL ASSESSMENT AND PREDICTION

Overview

NOAA's forecast and warning services mitigate the effects of a broad range of environmental hazards on public safety and the national economy. NOAA's traditional expertise in weather prediction has been expanding in scope and proficiency, thanks to continuing research and innovation in technology, scientific understanding, modeling, and operational predictions. Improvements in forecasting floods, water resources, hurricanes, tornadoes, air quality, magnetic disturbances, seasonal climatic variability, and climatic changes have profound effects on decisions of farmers, businesses, the public, and policy makers. These forecasts represent the skillful integration of observations with research on environmental phenomena, and rely on powerful data processing and information dissemination systems.

Much of NOAA's research into long-term phenomena is conducted in conjunction with the USGCRP. The agency's work in seasonal, interannual, decadal, and centennial scale variability in climate is coordinated with efforts in the academic community, other agencies, and other nations.

Advance Short Term Warning and Forecast Services

NOAA's research efforts in short term warnings and forecasts focus on six areas: severe weather, hydrological research, extended range weather forecasts, coastal ocean forecasts, the space environment, and observing systems. In other areas, NOAA relies heavily on outside providers of research and technology.

The agency aims to improve understanding of severe storms' structure in order to develop new algorithms, models, and forecasting techniques, and to improve the accuracy and lead-time of forecasts and warnings. NOAA and its research partners are exploring both new

observing capabilities, such as wind profilers and lidars, and applications of the new technologies in the National Weather Service Modernization.

NOAA's hydrological research emphasizes development of numerical and physical models that incorporate not only measurements of water in rivers and streams, but also observations of rainfall and soil moisture attained with modernized Weather Service observing systems. In parallel to extending the range of the weather forecasts to a week or more, NOAA will produce river-level, flood, and drought forecasts with lead times long enough to be of much greater use to national and state river system managers, flood planners, and industrial planners. Likewise, oceanographic and meteorological research by four of NOAA's line and program offices will develop coastal forecasts to assist planners and marine industries.

Solar disturbances can cause ground and space power and communication fluctuations, disrupting civilian, military, and commercial activities. NOAA is seeking improved forecasts of fluctuations. Thoroughly integrated with military and academic efforts, the program's central aims are to make optimal use of new (non-NOAA) data sources and to gain a better understanding of solar disturbances, their propagation through interplanetary medium, and their interactions with the earth's atmosphere.

Current NOAA research in observing systems stresses data not covered by the NWS modernization, but pivotal to forecast improvements. One current priority is defining an upper air observing system to supersede the expensive and aging current system; daily NWS forecasts are critically dependent upon continuous upper air observations. This complex problem involves characterizing candidate measuring systems, investigating their effect on current prediction models, and conducting sensitivity studies to determine the total coverage required in time and space.

Implement Seasonal to Interannual Climate Forecasts

The oceanic and atmospheric phenomena that control seasonal to interannual variability in climate are driven primarily by the El-Niño-Southern Oscillation (ENSO) system of the tropical Pacific Ocean. In the past ten years, research coordinated by USGCRP has illuminated many of the complex interactions through which ENSO causes variation in rainfall and temperature worldwide. NOAA is presently able to produce skillful forecasts of ENSO events up to one year in advance.

NOAA is translating this improved understanding into operational forecasts, so that they can be used to guide economically significant decisions for industries such as agriculture and tourism. The agency has identified four research priorities for its operational system: understanding key climatic processes, improving forecast skill, improving observing systems, and assessing social and economic impacts of the forecasts. To meet these needs, USGCRP is coordinating the planning and funding of a joint research program to be performed by NOAA and its academic partners.

Predict and Assess Decadal to Centennial Change

NOAA plays a leading role in national and international research efforts to model and predict decadal to centennial climate changes. NOAA offers American policy makers its own research results, as well as expert evaluations and assessments of the varied observations and hypotheses of the national and international community. NOAA's research in decadal to centennial change aims at understanding in three areas: atmospheric and oceanic processes that contribute to long term climate variation; chemistry of stratospheric ozone; and long term regional variation in ground level ozone.

NOAA contributes to several aspects of the USGCRP program in long term climate variation. NOAA investigates the earth's energy budget and the behavior of greenhouse gases, and tries to improve their representation in predictive models. NOAA's studies stress the integration of observations into models, both to improve the models and to determine whether predictions are matched by observations. To facilitate model verification by hindcasting, and to increase understanding of climate processes, NOAA conducts programs to catalogue, verify and improve both historical and paleoceanographic climate records. Finally, NOAA and its partners are designing and conducting a research program and data system to define the ocean's important and poorly understood role in climate, including the role of the ocean in the global carbon cycle, and the long term role of hydrothermal mid-ocean ridge processes in ocean chemistry.

NOAA contributes crucial guidance and expertise to the national effort to quantify stratospheric ozone decline and understand its cause. NOAA's experts provide balanced scientific advice to decision makers regarding protection and recovery of the ozone layer. NOAA also cooperates with EPA in a research program designed to improve the understanding of the key processes involved in the production, transport and removal of pollutants in regional areas of the United States, particularly ozone abundance in rural areas. Modeling of air-quality changes is used to evaluate and assess regional air quality problems. This work complements EPA's research activities, and will be an important underpinning for effective ozone regulation.

Promote Safe Navigation

NOAA's mandate to maintain marine, aeronautical, scientific and engineering navigation and positioning systems requires the integration of new technologies and recent breakthroughs, such as Geographic Information Systems (GIS) and the Global Positioning System (GPS), into the agency's traditional services. The nation's most pressing needs for improvement in this area are maintenance of coastal charts, water level predictions, digital data for use with electronic charts and GPS navigation, and an updated, consistent spatial reference framework. NOAA's research in integrating new technologies into its goals covers geodesy, hydrographic and photogrammetric technology, and marine coastal forecasting.

FURTHER EFFORTS NEEDED

- WHY is further research into oceanic and atmospheric systems needed for NOAA's mission?

- WHAT is NOAA's role in this research?

NOAA acts, in some sense, as an agent between the nation and its environment, helping businesses, governments, and individuals operate within the constraints imposed by nature. In an increasingly high tech society, human activities become more sensitive to natural variations, from the airline pilots whose safety depends on NOAA's measurements and predictions of high altitude conditions, to the fisheries manager whose limitations on fishing activity depend on NOAA's understanding of fish populations. The agency's mission changes with the human capacity to use, alter, deplete, and contaminate the earth's resources and natural systems; and that capacity to modify natural systems grows in tandem with expansion in population and advances in technology. NOAA relies on research to carry out its ever-changing prediction and stewardship missions.

The consequences of the intensifying interactions between humans and the environment are not always predictable or avoidable, but the cost of ignorance can be high. For example, some fisheries stocks have collapsed as a result of commercial practices or destruction of habitat; and release of manufactured chemicals into the atmosphere has led to acid rain and depletion of stratospheric ozone. Possibly, research that leads to better understanding of atmospheric and oceanic systems will allow us to avoid some disagreeable future repercussions. However, it is certain that without a healthy, ongoing research enterprise, the nation will be ill prepared to cope with environmental surprises.

A related impetus for NOAA is the rapid advance of technology. This confronts NOAA with both the opportunity to accomplish its mission more efficiently, and the risk of obsolescence of its products and services. Technologies developed for scientific, military, and industrial use can be adapted for NOAA's missions. However, the path from recognition of a potential application to operational capability is a complex R&D process requiring adaptation of the technology to NOAA's needs and demonstration of its effectiveness and broad scale applicability. To illustrate:

- The ongoing Weather Service Modernization, with advanced radars, satellite sensors, sophisticated models, and computing power, is the operational product of years of research and development. The measurements it provides may initiate the next cycle of R&D in understanding weather and storms.

- The GPS system, launched by the military, is revolutionizing navigation and positioning. NOAA services will require a concerted research effort to fulfill the promise of this powerful technology.

These are relatively straightforward examples of NOAA's research requirements, from a set that will become ever more complex and interdisciplinary. Some of the needs for the coming decade are already known, although the means to execute them may not be. Complex environmental problems, including the ozone hole, climate change, coastal management, and fisheries recovery, will require multi-disciplinary, long-term commitment to observation and research. Economics and social sciences research will be needed to inform NOAA's management and policy advising missions. Improving forecasting capability in seasonal to interannual climate requires integrated modeling, observations, and process studies. Research based on existing advances in observing systems can lead to improvements in short- and long-term forecasting, and design of new observing networks will require work by researchers and modelers, to ease assimilation of data.

The array and difficulty of these issues are too great to be tackled piecemeal. NOAA must maintain talent capable of steering both the research that underlies its mission and the applied investigations it needs for operations. NOAA's research capability, for example, must be sufficient to set requirements and priorities for its partners in fundamental fields such as geophysical fluid dynamics, homogeneous and inhomogeneous chemistry, marine biology, and wave propagation in irregular media. Likewise, NOAA's applied science and engineering capability must be sufficient to identify and adopt promising results and technologies.

PROPOSED ACTIONS

To make certain that it maintains the research capability necessary for its mission, NOAA has set several broad organizational and topical goals for its line offices and its research programs. The agency will also continue its efforts to integrate research goals into its planning process, and will institute a procedure to regularly assess progress toward its program objectives, and to guide the development of research strategies for each program.

NOAA will strengthen the links between the research activities conducted through OAR and the operational activities of the other line organizations. Regular contact will ensure that researchers are aware of the needs of the forecasters and regulators, and that the operational personnel can develop ways of integrating innovations into their activities. This need is particularly acute with respect to NOAA's oceanographic missions, which can benefit from OAR's experience with research that has led to advances in atmospheric models and observing systems. Likewise, the planning of research and modeling will be better integrated with planning observation networks and monitoring programs. Model-based insights can be useful in designing effective observational networks, to serve both operational and research needs. Conversely, data is necessary for improvement of models, and incorporation of observations into models should be as seamless as possible.

NOAA's need for integrated ecosystem science is a broad challenge linking the missions of all line offices and several Strategic Plan goals. Ecosystem science involves the physics,

biology, chemistry and geology of a region and their mutual interactions and dependencies. These scientific capabilities presently exist in separate organizations within NOAA, and the agency is instituting several means to improve coordination. To support the remote sensing needs of ecosystem science, as well as other marine missions, NESDIS and NOS are making an effort to combine and expand their programs in ocean remote sensing. A new Standing Committee on Biodiversity is formulating an agency biodiversity strategy. In addition, NOAA will consider using its areas of specially designated management responsibility, such as the National Marine Sanctuaries and National Estuarine Research Reserves, as focal points for the agency's ecosystem science research. Using an ecosystem framework, and with the focus on its mandated management areas, NOAA will strive to assemble cooperative teams from inside and outside the agency to develop the science to understand these systems, building on natural complementarities in the mission of other federal agencies.

To ensure that research needs are met as efficiently as possible, NOAA and the University community will continue to examine and strengthen their partnership. In the wake of a successful Partnership Conference in autumn 1994, the two groups will organize two joint meetings per year to improve coordination and cooperation in formulating research strategies and priorities. With limits on budgets and personnel, NOAA will be examining carefully, and likely increasing, its reliance on outside sources for research. To maximize the benefits of the changing partnership, both parties must realize the long-term commitments necessary to meet each others' needs: Universities require a steady commitment of funds to guide their hiring and planning; NOAA requires a commitment to reliably meet the agency's mission goals.

NOAA's aim must be to optimize both its internal and external research investment, maximizing cooperation and minimizing duplication. This is the agency's, indeed the nation's, central management challenge in designing research programs, and NOAA's efforts mesh with the national strategy. The National Science and Technology Council (NSTC) and its Committee on Environment and Natural Resources (CENR) are coordinating interagency research planning, and NOAA is taking a leadership role in CENR's efforts. The research strategies of NOAA's line offices must be formulated to contribute both to cross-cutting missions defined in this Strategic Plan, and to leverage and complement research coordinated by CENR.

The Chief Scientist's Office is completing a review of the relevance of NOAA's research to the Strategic Plan goals, and has concluded that progress toward the goals should be measured periodically at the agency level, through a review mechanism that is incorporated into NOAA's strategic planning process. Different from a peer review, these assessments will invite internal and external reviewers to comment on NOAA's progress toward its program and organizational research goals.

NOAA has operational responsibility to deliver products and services and to manage resources. No other agency is committed to measuring, monitoring and understanding

atmospheric and marine systems over the long term. These responsibilities impel NOAA to coordinate basic research and operations, to aggressively incorporate new technology, and to maintain the research expertise necessary to tailor scientific and technical progress to the agency's needs.

TABLE 1. ENVIRONMENTAL RESEARCH LABORATORIES

Aeronomy Laboratory	Boulder, CO	Atmospheric chemistry, physics, and dynamics, focusing on air quality, stratospheric ozone depletion, and climate change
Air Resources Laboratory	Silver Spring, MD	Transport, dispersion, air surface exchange and transformation of pollutants and aerosols, and relation to air quality, emergency preparedness and response, and climate trends.
Atlantic Oceanographic and Meteorological Laboratory	Miami, FL	Atmospheric chemistry; observations related to climate change, hurricane research, fisheries recruitment, and nutrient enrichment
Climate Diagnostics Center	Boulder, CO	Diagnostic studies of climate variability; data management systems for observational and model-generated data
Climate Monitoring and Diagnostics Laboratory	Boulder, CO	Long-term measurement and analysis of greenhouse gases, aerosols and ozone, related to climate change and stratospheric ozone depletion.
Environmental Technology Laboratory	Boulder, CO	Development, demonstration, and transfer of cost-effective remote measurement systems for weather, climate, and coastal applications.
Geophysical Fluid Dynamics Laboratory	Princeton, NJ	Develop numerical models related to weather, climate and ocean predictability.
Great Lakes Environmental Research Laboratory	Ann Arbor, MI	Integrated, interdisciplinary research on coastal, estuarine, and Great Lakes environments, in support of management
National Severe Storms Laboratory	Norman, OK	Numerical and conceptual models of storms and studies of mesoscale weather processes
Pacific Marine Environmental Laboratory	Seattle, WA	Observation and process studies in oceanography, marine meteorology, and related subjects
Space Environment Laboratory	Boulder, CO	Research, monitoring, assessment, and forecasting of near-earth space environment, to mitigate economic loss and promote public safety.

TABLE 2. FISHERY SCIENCE CENTERS

Center	Location
Northeast Fisheries Science Center	Woods Hole, Mass.
Southeast Fisheries Science Center	Miami, Fla.
Southwest Fisheries Science Center	La Jolla, Calif.
Alaska Fisheries Science Center	Seattle, Wash.
Northwest Fisheries Science Center	Seattle, Wash.

TABLE 3. NOAA JOINT INSTITUTES

Institute	University	Collaborating Labs	Research Areas
Cooperative Inst. for Research in Environmental Sciences (CIRES)	Univ. of Colorado, Boulder, CO	AL, ARL, CDC, CMDL, NSSL, ETL, FSL, SEL, NESDIS	Atmospheric and climate dynamics, cryospheric and polar processes, environmental chemistry and biology
Coop. Inst. for Research in the Atmosphere (CIRA)	Colorado State Univ., Fort Collins, CO	FSL, NSSL, ETL, NWS, NESDIS	Local weather forecasting, air quality, economic and social aspects of weather forecasting, satellite applications
Coop. Inst. for Mesoscale Meteorological Research (CIMMS)	Univ. of Oklahoma, Norman, OK	NSSL , NWS	Convective and mesoscale research, forecast improvements, socio-economic effects of weather and climate
Coop. Inst. for Limnology and Ecosystems Research (CILER)	Univ. of Michigan, Ann Arbor, MI	GLERL	Coastal and nearshore processes, climate and large lake dynamics, large lake ecosystem structure and function
Coop. Inst. for Marine and Atmospheric Studies (CIMAS)	Univ. of Miami, Miami, FL	AOML, SEFSC, NESDIS	Climate variability; marine gases, aerosols and climate; fisheries ecology and ecosystem dynamics
Joint Inst. for the Study of the Atmosphere and Ocean (JISAO)	Univ. of Washington, Seattle, WA	PMEL, AKFSC, NWFSC	Climate, environmental chemistry, estuaries, and fisheries oceanography
Joint Inst. for Marine and Atmospheric Research (JIMAR)	Univ. of Hawaii, Honolulu, HI	PMEL, CMDL, NMFS, OGP, NWS	Equatorial and fisheries oceanography, tsunamis, climate, tropical meteorology

Institute	University	Collaborating Labs	Research Areas
Cooperative Institute for Meteorological Satellite Studies (CIMSS)	Univ. of Wisconsin, Madison, WI	NESDIS	Meteorological research using satellite technology
Coop Inst. for Arctic Research (CIFAR)	Univ. of Alaska, Fairbanks, AK	PMEL	Arctic research

Table 4 SEA GRANT PROGRAMS

Sea Grant Program	Location
Alaska Sea Grant	Univ. of Alaska Fairbanks, AK
California Sea Grant	Univ. of California, San Diego San Diego, CA
University of Southern California Sea Grant	USC Los Angeles, CA
Connecticut Sea Grant	Univ. of Connecticut Groton, CT
Delaware Sea Grant	Univ. of Delaware Newark, DE
Florida Sea Grant	Univ. of Florida Gainesville, FL
Georgia Sea Grant	Univ. of Georgia Athens, GA
Hawaii Sea Grant	Univ. of Hawaii Honolulu, HI
Illinois/Indiana Sea Grant	Univ. of Illinois Champaign, IL
Louisiana Sea Grant	Louisiana State Univ. Baton Rouge, LA
Maine/New Hampshire Sea Grant	Univ. of Maine Orono, MN Univ. of NH Durham, NH
Maryland Sea Grant	Univ. of Maryland College Park, MD
MIT Sea Grant	Mass. Institute of Technology Cambridge, MA
WHOI Sea Grant	Woods Hole Oceanographic Inst. Woods Hole, MA
Michigan Sea Grant	Univ. of Michigan Ann Arbor, MI
Minnesota Sea Grant	Univ. of Minnesota St. Paul, MN
Mississippi/Alabama Sea Grant	MS/AL Sea Grant Consortium Ocean Springs, MS
New Jersey Sea Grant	NJ Marine Sciences Consortium Ft. Hancock, NJ
New York Sea Grant	SUNY Stony Brook Stony Brook, NY/ Cornell Univ. Ithaca, NY
North Carolina Sea Grant	Univ. of North Carolina Chapel Hill, NC
Ohio Sea Grant	Ohio State Univ. Columbus, OH
Oregon Sea Grant	Oregon State Univ. Corvallis, OR
Puerto Rico Sea Grant	Univ. of Puerto Rico Mayaguez, PR
Rhode Island Sea Grant	Univ. of Rhode Island Narragansett, RI
South Carolina Sea Grant	South Carolina Sea Grant Consortium Charleston, SC
Texas Sea Grant	Texas A&M Univ. College Station, TX
Virginia Sea Grant	Virginia Graduate Marine Sci. Consortium Charlottesville, VA
Washington Sea Grant	Univ. of Washington Seattle, WA
Wisconsin Sea Grant	Univ. of Wis.-Madison Madison, WI

Table 5 NURP INSTITUTIONS

Regional Center	Location
Northeastern U.S. and Great Lakes	University of Connecticut - Avery Point Groton, CT
Southeastern U.S. and Gulf of Mexico	University of North Carolina- Wilmington Wilmington, NC
Caribbean	Caribbean Marine Reserach Center Covington, VA
U.S. West Caost and Alaska	University of Alaska - Fairbanks School of Fisheries and Marine Science Fairbanks, AK
Hawaii and the Western Pacific	University of Hawaii - Manoa Honolulu, HI
Middle Atlantic Bight	Rutgers University - Cook Campus New Brunswick, NJ

OBSERVING SYSTEMS

OVERVIEW

NOAA's most fundamental activity is measuring the physical, chemical, and biological properties of Earth, emphasizing its atmosphere and oceans. This is prerequisite to nearly everything else NOAA does, from assessments and predictions to warnings. Observational capability is central to NOAA's responsibilities. NOAA envisions a modern, integrated, comprehensive system of observing platforms and networks providing data needed for environmental assessment, prediction, and stewardship.

By 2005, increases in computing power will enable atmospheric and oceanic models to be run with greater spatial resolution and more realistic representation of the physical processes. Advances in communications will provide increased access to environmental data and information. These factors will raise demand for more high quality data and forecasts. In addition, demand will increase for delivering observations in real time. A huge challenge of the 21st century will be to keep up with the growing demand for accurate, complete, and timely environmental data. This is a direct challenge to NOAA's observing and monitoring responsibilities.

NOAA plans to (1) determine measurement needs, (2) conduct an inventory of present systems, (3) assess the extent to which needs can be satisfied, and (4) recommend improvements and additions. Important recent enhancements to the observing systems have improved NOAA's capability to provide more timely and accurate warnings. Future systems will provide additional improvements. Some have been under development for more than a decade; others are just emerging. They must be tested to determine the best mix for implementation.

The ten-year NWS modernization effort has addressed deficiencies of observing systems used primarily in warnings and forecasts. Weather forecasts from 3 hours to 3 days have improved greatly. NWS plans to continue to upgrade its observing capabilities.

Many of the remaining observational deficiencies are related either to climate or to enhancing the oceanic data base. Recent research has demonstrated that clues to regional climatic phenomena require investigation on a global scale. The monitoring requirements on global scales are so great that they are achievable only through interagency and international cooperation. Recent international agreements have covered gaps in satellite coverage created by instrument failure. Other international mechanisms are in place to achieve cooperation on a range of observing systems helpful to NOAA's mission. Two such mechanisms are the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS), whose observational requirements overlap considerably.

CAPABILITIES

Observing Platforms

The National Environmental Satellite, Data, and Information Service (NESDIS) operates Geostationary Operational Environmental Satellites (GOES) and Polar-orbiting Operational Environmental Satellites (POES). GOES consists of two satellites located (nominally) over 75 and 135 degrees west longitude. GOES satellites collect visible and infrared imagery, temperature and moisture sounding, and space environment parameters. GOES data are principally used in severe storm monitoring and daily weather forecasts.

POES consists of two primary satellites providing worldwide imaging and sounding data, space environment observations, and atmospheric ozone measurements. POES satellite data support 3-5 day weather forecasts, and many environmental products such as vegetation indices, sea surface temperature, and extent of snow cover.

NOAA also has program oversight responsibility for the operation of Landsats 4 and 5 earth sensing satellites. The Earth Observation Satellite Company operates the satellites. NOAA will operate Landsat 7 with the National Aeronautics and Space Administration (NASA) and the U. S. Geological Survey (USGS).

NOAA Corps Operations (NC) operates 15 research and survey ships from 27.5 meters to 92.4 meters in length and 220 to 4033 tons in displacement. The ships support atmospheric, oceanic, coastal, and estuarine missions using sensor and sounder systems, fishery equipment, and laboratories supported by on-board data collection and processing systems, and deck handling equipment. Eight ships can support fishery resource assessment, three support hydrographic surveys, and four support oceanographic and coastal ocean research. Small craft operated by NOAA line offices complement the ships for near shore data collection.

NC operates 13 uniquely configured aircraft:

- ***2 WP-3D Orions equipped for improved hurricane forecasting, they also collect meteorological, climate, air chemistry, and oceanographic observations in support of severe storm research, pollution analysis and climate change.***

- 1 Cessna Citation and 1 Turbo Commander perform photogrammetric surveys for nautical and aeronautical charting.

- 1 Turbo Commander and 1 Shrike Commander assess snow accumulation for river forecasting.

- 1 Shrike Commander performs aeronautical chart updating surveys.

- 2 Twin Otters and 1 helicopter perform surveys for fishery resource and protected species management.
- 1 Twin Otter will soon be equipped for air pollution studies.
- 2 single-engine aircraft and 3 helicopters support observations and logistics.
- 2 helicopters support a hydrographic survey in cooperation with the Army Corps of Engineers.

The Office of Oceanic and Atmospheric Research's (OAR) National Undersea Research Program (NURP) operates platforms and vehicles, including:

- a 2000-meter depth-capable submersible
- a 65-meter scientific support ship
- 2 1000-meter depth-capable remotely operated vehicles (ROV)
- several 200-meter depth-capable ROVs
- an autonomous undersea vehicle (AUV)

NURP provides a saturation diving laboratory capable of supporting five scientists for 10-day missions. This underwater laboratory may be relocated based on NOAA research requirements.

The National Weather Service's (NWS) NOAA Data Buoy Center operates 71 moored buoys along the coast of the United States and in the Great Lakes. They provide real-time measurements of barometric pressure, wind speed and direction, air temperature, sea surface temperature, and wave height to support coastal forecasts and warnings.

Observing Networks

NWS operates a network of weather radars. The current network is being replaced by 160 Next Generation Weather Radars (WSR-88D, but commonly referred to as NEXRAD) capable of detecting the presence and providing the speed and direction of motion of severe weather elements and providing quantitative area precipitation measurements. Thirty-nine NEXRAD installations will be operated by the Federal Aviation Administration (FAA) and the Department of Defense (DOD).

NWS, in cooperation with FAA and DOD, is automating the national network of surface observation stations with approximately 870 Automated Surface Observing Systems (ASOS).

ASOS measures wind speed and direction, temperature, liquid precipitation accumulation, visibility, cloud height, precipitation identification, and barometric pressure.

NWS performs two radiosonde observations daily at 93 stations throughout the contiguous United States, Alaska and the Pacific. They record profiles of temperature, humidity, and wind from the surface to the stratosphere.

NWS coordinates 10,900 volunteer observing sites at which daily rainfall and snowfall amounts are recorded for climate purposes. At more than 9000 of these sites daily maximum and minimum temperatures are also collected and reported. Selective observations of other parameters are included (e.g., river stage, soil temperature, etc.).

NWS contracts for national lightning data. The contract provides for real-time reporting of cloud-to-ground lightning strike location, strength, and polarity. Coverage includes the contiguous 48 United States and adjacent waters to 250 km.

NWS coordinates approximately 1200 volunteer observing ships contributing globally distributed standard marine surface observations. National Ocean Service (NOS) and the Office of Oceanic and Atmospheric Research (OAR) operate a complementary program deploying Shipboard Environmental [data] Acquisition Systems (SEAS) aboard 140 volunteer vessels that provide semi-automatic real-time relay of surface and upper ocean measurements.

The Office of Global Programs (OGP), OAR, NOS, and the Scripps Institution of Oceanography support the annual global deployment of several hundred drifting surface buoys providing real-time measurements of barometric pressure, air temperature, sea surface temperature, and ocean surface currents.

OGP supports NOS and the University of Hawaii in operating approximately 70 sea level gauges at island and coastal locations in all three ocean basins.

NOS operates the National Spatial Reference System (NSRS) consisting of the National Earth Orientation Service (NEOS) and Continuously Operating Reference Stations (CORS). NEOS is an interagency program providing the earth orientation data on polar motion, universal time, and nutation. NOS contributes to the support of three of the approximately 30 Very Long Baseline Interferometry (VLBI) receivers for NEOS and correlates VLBI input. The CORS network will have more than 100 fixed, continuously operating GPS tracking stations operated in partnership with the FAA, Coast Guard, and Army Corps of Engineers.

NOS implements the Physical Oceanographic Real-Time Systems (PORTS) to monitor water currents and levels and wind measurements in bays and harbors.

NOS is responsible for the National Water Level Program (NWLP). They operate the National Water Level Observational Network (NWLON) consisting of 140 primary,

permanent tide gauges at U.S. coastal and island locations and 49 Great Lakes water level stations. NOAA is upgrading the NWLP with the Next Generation Water Level Measurement System (NGWLMS). The NWLP also supports other NOAA, federal, state, and local programs requiring tidal data and NWS warnings (tsunami and storm surge).

NOS manages and coordinates the U.S. Interagency Arctic Buoy Program, a collaborative effort that draws operating funds and services from eight government agencies and/or programs. Data from a network of drifting buoys in the Arctic are reported through the Global Telecommunications System and are used for operational weather and ice forecasts and for climate research.

OAR operates 70 buoys across the tropical Pacific measuring wind speed and direction, air temperature, sea surface temperature, and upper ocean temperatures to 500 meters. Some buoys are instrumented for solar radiation, humidity, rainfall, and upper ocean currents.

OAR operates four Climate Monitoring and Diagnostic Laboratory (CMDL) baseline observatories at Barrow, AK; Mauna Loa, HI; American Samoa; and the South Pole, to monitor, detect, quantify, and assess changes in concentration of greenhouse gases, stratospheric and tropospheric ozone, aerosols, and water vapor. The Mauna Loa Observatory is in the International Network for Detection of Stratospheric Change. Data are supplemented by a 34 station global flask sampling network monitoring carbon dioxide and methane concentrations.

OAR has consolidated NOAA's solar surface radiation (SURFRAD) and ultra-violet B radiation monitoring programs under the Integrated Surface Irradiance Study (ISIS). This network measures surface irradiance, infrared radiation, and ultraviolet radiation in the continental United States, Hawaii, and Guam.

The Atmospheric Integrated Research Monitoring (AIRMon) program is operated by OAR in support of NOAA's mission for the Clean Air Act. This ground-based effort measures acidic precipitation, wet and dry deposition, and meteorological parameters and is designed to detect air quality and deposition changes resulting from emission changes. The majority of the 19 observing sites are in the Northeastern United States.

Developing Systems

The NOAA Wind Profiler Demonstration Network provides information on the vertical structure of the atmosphere. The Radio Acoustic Sounding System is being placed and tested at some wind profiler sites to measure vertical profiles of atmospheric temperature. Water vapor will be measured by a GPS based system and from specially-instrumented commercial aircraft. These will be major components of an advanced upper air sounding system, essential for weather forecasting.

The OAR Environmental Research Laboratories investigate and test many instruments for operational application. The research Doppler radar is used to refine NEXRAD algorithms, investigate storm development, and test new techniques such as polarized radar for estimating precipitation. Some OAR equipment is portable for use in field experiments, including 8 mm radar, microwave radiometer, and Doppler lidar. A network of wind profilers and bottom pressure recorders in the tropical Pacific is used to study tropical circulation and tsunamis. This is representative of much equipment throughout NOAA.

Application of active and passive hydro acoustics to fisheries stock assessment is promising. Other new techniques involving polarization lidar, video/laser, smart optical samplers, and acoustic sensors are being explored for their fisheries applications.

Non-NOAA Systems

OAR receives space environment data from the Defense Meteorological Satellite Program (DMSP), solar images from the DOD Solar Electro-Optical Network and the U.S. National Solar Observatory, and magnetometer data from the USGS/USAF Intermagnet program. NOAA is also receiving solar x-ray images from the Japanese YOKOH satellite. OAR will generate geomagnetic storm alerts using NASA WIND and ACE missions' solar wind data.

Oceanographic data, including ocean color and global surface wind vector fields, will be available from the Advanced Earth Observation Satellite (ADEOS). All-weather synthetic aperture radar images will be available from RADARSAT and ERS-2 and altimetry data from TOPEX/POSEIDON and the Geosat follow-on programs.

NOAA uses C-130 aircraft from DOD in hurricane reconnaissance, ER-2 from NASA for stratospheric ozone depletion studies, and National Science Foundation aircraft occasionally in atmospheric research.

OAR's NURP provides access for NOAA and civilian scientists to US Navy submersibles and remotely operated vehicles (ROV) for research to 6000 meters depth, and to nuclear submarines for arctic research. NURP is NOAA's contact for manned submersible and ROV charters and partially supports the 4500 meter depth-capable ALVIN.

Formerly classified DOD data from the Integrated Undersea Surveillance System (IUSS) provides information on hydrothermal venting and marine mammal migration. Over-the-Horizon B radar provides information on surface winds, useful in hurricane forecasts, and surface ocean currents. Data and products from DMSP are produced in cooperation with DOD under Shared Processing.

Meteorological observations are reported routinely by commercial and general aviation through the Meteorological Data Collection and Reporting System (MDCRS). Data from

stream gauges operated by other government agencies are routinely factored into NOAA forecasts and warnings.

The International Dimension

As the U.S. earth systems agency, NOAA cooperates with scientists and institutions in many other nations. NOAA depends on them for access to data, use of research facilities, access to people and geographic areas, and technology transfer. Given that we work in an interdependent world, NOAA must improve its effectiveness at lower cost through cooperation and coordination with other nations and international organizations. When it is advantageous, NOAA uses foreign research vessels, satellites, aircraft, equipment and facilities.

Following is a table of NOAA mission dependency on observing systems. A column represents one of NOAA's strategic plan mission elements; a row represents an observing system. **C** indicates critical dependency: the absence of system data or support would preclude the provision of all or part of the product or service, or would seriously degrade its quality. **B** indicates that data or support improves the product or service.

MISSION/SYSTEM DEPENDENCY	BSF	RPS	SHC	PSN	STWF	S/I	D/C
GOES Satellites	B		C		C	C	C
POES Satellites	B	B	C		C	C	C
LANDSAT	B		B	B			B
Ships\Small Craft	C	C	C	C	B	C	C
Aircraft	B	C	C	C	C	B	B
Undersea Facilities	B	B	C				C
Moored Buoys	B		C		B	B	C
Weather Radar					C	B	B
Surface Weather Obs			B		C	C	C
Radiosonde Obs					C	B	C
Volunteer Weather Obs	B	B	B		C	C	C

MISSION/SYSTEM DEPENDENCY con't	**BSF**	**RPS**	**SHC**	**PSN**	**STWF**	**S/I**	**D/C**
Lightning Obs					C		B
Volunteer Obs Ships	B	C	C		C	C	C
Drifting Buoys		B	C		B	C	C
Sea Level	B	B	B			C	C
Spatial Reference Sys	B		C	C	B	C	C
PORTS*	B	C	C	C	B		B
Nat'l Water Level Prog	B	C	C	C	C		C
Arctic Drifting Buoys					C	C	C
TAO Array	B	B			B	C	C
CMDL Observatories							C
ISIS*	B				B		C
AIRMon*	B		B		B		C
WPDN/TPPN*					C	C	C

*PORTS-Physical Oceanographic Real-Time System
ISIS-Integrated Surface Irradiance Study
AIRMon-Atmospheric Integrated Research Monitoring program
WPDN/TPPN Wind Profiler Demonstration Network/Trans-Pacific Profiler Network.

CURRENT EFFORTS

Build Sustainable Fisheries

Building sustainable fisheries depends on information collected by NOAA. For example, assessing fishery resources, improving fishery predictions, and reducing bycatch all rely on resource monitoring by NOAA research vessels, aircraft, submersibles, and fixed-position and drifting buoys, as well as data from cooperating agencies and governments. These observations aid in remote sampling of biological populations, collection of biological data for ecological modeling and implementing resource surveys to assess fisheries. They are

fishery-independent measures of resource abundance. Measurements of water and air temperature, wind, salinity, current, precipitation and air pressure support predictions and analyses needed to build sustainable fisheries.

Recover Protected Species

The Endangered Species (ESA) and Marine Mammal Protection Acts (MMPA) require that stocks of protected species be assessed and monitored. Use of NOAA's ships and aircraft, privately chartered vessels, and volunteer observing ships fulfills these requirements. NOAA collects data concurrently for protected species and fishery resources. NOAA will expand its protected species monitoring network by combining observer expertise with such monitoring systems as Physical Oceanographic Real-Time Systems (PORTS) and National Water Level Program (NWLP). They and others provide data on ocean currents, water levels, water temperatures, and tide systems. By collecting data, NOAA helps to assure the conservation of diverse marine ecosystems and avoids adverse interactions between protected species and users of marine resources.

Sustain Healthy Coasts

The Sustain Healthy Coasts strategic plan requires systematic observations of the coastal atmosphere and ocean/bays/estuaries. In general, satellite data sources such as Landsat and ocean color sensors have a coarse resolution best suited to cue *in situ* observing systems that monitor coastal ecosystems and assess damage. These systems include observations from ships, aircraft, submersibles, buoys, radiosondes, surface weather stations, PORTS, and tide/water level stations. Assessments of fish and invertebrate stocks provide understanding of the causes and significance of ecological changes.

Advance Short-term Warning and Forecast Services

Observations from polar and geostationary satellites, radiosondes, ships and aircraft, weather radars, the surface weather and lightning observation networks, stream gauges, water level gauges, PORTS, and cooperative observers all contribute to warnings and forecasts. Similar observations from other nations contribute to our national forecast capabilities. Wider deployment of the Wind Profiler Demonstration Network (WPDN) beyond the 30 now operational and implementation of new systems, such as Radio Acoustic Sounding System (RASS), water vapor measurements from GPS satellites, the NWLP and aircraft automated sensors would provide improved forecast services and contribute to a more efficient mix of observing systems.

Implement Seasonal to Interannual Climate Forecasts

NOAA has helped advance short-term climate analyses and predictions as the lead agency in the United States for the Tropical Ocean Global Atmosphere (TOGA) Program. The TOGA

Observing System (TOS) collects many oceanic and atmospheric observations needed to initialize and validate climate predictions. TOS is a multinational research funded program supported by NOAA involving primarily in situ observing systems in the tropical Pacific. It consists of: Tropical Atmosphere Ocean Array (TAO), Surface Velocity Program (SVP), Volunteer Observing Ship Expendable Bathythermograph Program (VOS-XBT), Indo-Pacific Sea-Level Program, and Trans-Pacific Profiler Network (TPPN). Measurements from TOS are complemented by such satellite-based systems as NOAA's Polar-orbiting Operational Environmental Satellites (POES) (sea-surface temperature) and foreign microwave scatterometry (surface wind velocity) and radar altimetry (sea level).

Predict and Assess Decadal to Centennial Change

NOAA's current observing capacity is geared to meet the agency's weather forecasting responsibilities, such as severe weather warnings and short-term forecasts. Researchers in climate and global change must use the operational networks to acquire and develop data for climate monitoring and prediction. Consequently, climate quality data from satellites, in situ and remote-sensing land-based observing systems, aircraft, ships, submersibles, and buoys are extremely important for global climate analysis. In contrast, the Climate Monitoring and Diagnostic Laboratory (CMDL) monitors greenhouse gases, stratospheric and tropospheric ozone, aerosols, and water vapor globally specifically for climate and global change applications. NOAA is strengthening its air quality monitoring networks.

Promote Safe Navigation

Improving navigation requires accurate, complete, and timely data be disseminated to the navigator. Sonar equipped NOAA ships and boats acquire hydrographic sounding data used in charts of navigable waters. NOAA aircraft carry out photogrammetric and visual surveys necessary to define the coastline, produce aeronautical charts, and chart airports. NWLP data provides mariners with observed and predicted water levels. PORTS collects water level, current and wind data and provides the information in real time to ship pilots and other mariners. The National Spatial Reference System (NSRS) is essential to all navigation; it provides the reference for all latitudes and longitudes readings and the standard for the most accurate Global Positioning System (GPS) navigation.

FURTHER EFFORTS NEEDED

NOAA manages an ambitious observing and monitoring program. Issues discussed in the seven main elements of this plan require that we maintain many existing networks and upgrade others. Improvements in warnings, services, and assessments are not possible without the essential ingredient of reliable observations. Upgrades and enhancements must be sensitive to NOAA's stewardship of the long-term data record.

Improvement in some NOAA services requires additional observations, such as solar wind and global wind field. The four-dimensional atmospheric water vapor field is a prime example of an unmet data need for several NOAA missions.

Most observations were established to meet a specific requirement (the weather network is expected to operate indefinitely). Others were established with the expectation they would be discontinued, e.g., many ocean process studies. Some of the latter, originally justified for research, are now used in operations, or quasi-operationally. The lifetime of these systems such as WPDN and TOGA may be extended to meet both operational and research needs. Long range strategy includes developing mechanisms to ensure transition from research to operations.

To derive maximum benefit from observations, NOAA intends that many applications are considered when establishing observation requirements. Observing systems originally deployed for a single use must be adapted for multiple requirements to be cost-effective. For example, sensors deployed primarily to support forecasting are also used in climate studies. The valuable climate network of TAO buoys in the Pacific also provides crucial data to weather prediction models from an under-reported region.

A related problem is preserving the quality and continuity of observations. Climate change research requires many years of continuous data. Integrity of data is crucial to reliable assessment. Modifying existing observing systems must ensure that no gaps arise in data records. Overlapping measurements ensure calibration between existing and replacement systems.

Some established systems require refurbishment. NOAA is looking at a mixture of government-owned, leased and contract arrangements to meet its future needs for marine services. Some of NOAA's small fleet of aircraft is approaching the end of its useful life. NOAA ship and aircraft instrumentation and data collection computer technology needs regular upgrading. The upper air observing system employs decades-old technology. It is increasingly difficult to replace worn or defective equipment, since many necessary parts are no longer being manufactured. A steady decline of the cooperative observer network is cause for concern, particularly stations designated as part of the historical climate network.

Research into global climate change confirms the role of the oceans as an important factor in climate. GOOS and GCOS are established programs whose observational requirements overlap considerably. By working collectively through there established international efforts, a program can achieve its objectives by not competing unnecessarily for limited resources.

PROPOSED ACTIONS

NOAA is committed to upgrade its observing systems through such programs as the National Weather Service Modernization, including NEXRAD, ASOS, and the Advanced Weather

Interactive Processing System (AWIPS). NOAA has initiated Fleet Replacement and Modernization (FRAM) to ensure continuation of ship and small craft capability. An important component of FRAM is the Launch Modernization Project, which will support development and deployment of advanced survey sensors such as high-speed and high-resolution side scan sonar and shallow-water multibeam sonar systems. Completion of the Next Generation Water Level Measurement System will improve collection, communication, and dissemination capabilities. A modernization study of NOAA's aircraft, based on requirements, has been completed. NOAA's aircraft will be modernized as mission requirements dictate.

NOAA operates 15 research and survey ships, ranging in size from 27.5 meters to 92.4 meters in length and 220 to 4033 tons in displacement. These ships support the NOAA mission and carry out the essential data collection and monitoring that underpins NOAA research, fisheries management, and charting functions. Eight ships are dedicated to fisheries research and stock assessment; two support a mix of fisheries and coastal research; three conduct hydrographic surveys; and two are dedicated to oceanographic research and monitoring.

These ship platforms, coupled with charters, and contracts for data, will meet NOAA's projected near-term program requirements. In the longer-term, NOAA will be seeking to upgrade and replace aging vessels with a mix of owned and leased vessels, augmented by charters and contracts for data. Through the Fleet Modernization and Replacement (FRAM) Program, NOAA has already replaced it's older large oceanographic research ships with two modern efficient vessels and improved the condition of most other active ships. Major repairs have been completed on the DELAWARE II, the ALBATROSS IV, and the TOWNSEND CROMWELL that will extend their useful life for an additional 6 to 10 years.

Through the FRAM program, NOAA vessels have been equipped with modern computer and scientific systems, and advanced GPS positioning systems. Plans are nearing completion for adding three new shallow water multi-beam systems to existing hydrographic survey launches, that will provide 100 per cent bottom coverage in identifying hazards to navigation.

A systematic effort has begun to design an automated composite upper air observing system with emphasis on winds and water vapor. This system will serve short-range forecasts, warnings, and seasonal to interannual climate predictions and allow real-time calibration of satellite data for improved observations.

Several other systems, including CORS, PORTS, and SURFRAD, are being implemented. To carry out its fundamental mission of describing the physical, chemical, and biological properties of the earth and its environment, NOAA will vigorously pursue completion of these efforts.

In cooperation with its international and interagency partners, NOAA will initiate a program of ocean remote sensing to provide sea surface wind and temperature, ocean color, ice cover and altimetry observations.

Continuity is a significant criterion in new and replacement observing systems. Satellite continuity will be assured during the convergence of NOAA's POES and DOD's DMSP into the National Polar-orbiting Environmental Satellite System. As new and replacement observing systems are designed and deployed, the needs of potential users will be considered and satisfied to the extent practicable.

A significant part of observations is related to environmental research. These have a finite life-time, at the end of which observing activities are discontinued. NOAA will continue to enhance existing observations, procedures, and information management for climate monitoring. Successful research may indicate a need to continue these observations for an ongoing NOAA mission.

Years of research and more powerful computer models have provided an initial understanding to address changes in our environment. The critical limiting element is the set of observations. For the longer range problems involving climate and biogeochemical cycles, and for problems involving coastal areas, ocean observations are generally insufficient. The long-term strategy is to address this through interagency and international mechanisms where possible, since global demand for observations exceeds the financial capacity of any single agency or nation. The GOOS and GCOS are international programs which promise to meet observational needs in the 21st century.

ENVIRONMENTAL DATA AND INFORMATION SERVICES

OVERVIEW

Acquiring, archiving, integrating, and disseminating environmental data are critical to NOAA's mission to promote global environmental stewardship and describe, assess, and predict the Earth's environment. To fulfill its mission, NOAA must be able to convey observations for analysis and integration, process them into useful products, and rapidly disseminate the products to users.

It is difficult to imagine any sector of society not impacted by or dependent on NOAA environmental data. In the U.S., no airplane flies, no ship sails, no building is constructed, no roadbed is laid, no dam is built, no power plant is designed, no crop is planted without referring to NOAA data. Issues such as global competitiveness, sustainable development, and climate change require timely, high quality, and accessible data.

NOAA's vision is to make all environmental data and products readily available. NOAA information will be disseminated in the National Information Infrastructure (NII) for use by business, government, researchers, educators, and the general public. New information products and services will be made possible by nationwide networking at high data rates using advanced information technology.

NOAA intends for users anywhere in the U.S. to be able to search directories and inventories of NOAA data, preview or browse them, and retrieve data and information from National Data Centers, NOAA libraries, and remote archives.

CAPABILITIES

NOAA environmental information services form a critical link to informed policy decisions for our Nation, which is increasingly confronted by environmental problems that transcend national economies, including the greenhouse effect, ozone depletion, maintenance of biodiversity, atmospheric and marine pollution, fishery depletion, natural resources exploitation, navigation safety, and coastal zone management.

Other links to support informed decision making include describing the state of the ocean-atmosphere system, the health of living marine resource stocks, predicting future status, and assessing impacts of alternative responses. Impacts of environmental information dissemination include: savings of billions of dollars; an easy transition to a global free-market; and bolstering of all levels of education.

For example:

- **Reduced Environmental Assessment Uncertainty**: Facilitating the use of interagency databases and multi-disciplinary data sets will reduce uncertainties related to a comprehensive assessment of the changes and behavior of the Earth system.

- **Enhanced Ocean-Atmosphere Predictions**: Through improved management of data and its synthesis into user-targeted and policy-relevant information, the Nation will enhance observing, understanding, and predicting the state of the living ocean-atmosphere system, the living marine resources dependent on it, and the natural and human-induced drivers that modify it.

- **Increased Competitiveness of U.S. Industry**: NOAA will promote development of technologies encouraging increased competitiveness of U.S. industry, currently the world leader in computing, communication hardware, and software. NOAA's need for these technologies, DOC leadership in standards and technology development, and the administration's intent to target the information technology industry for a U.S. leadership role will combine to maintain U.S. leadership and capture a significant share of the world market in information technologies.

- **Increased Productivity and Improved Decision Making**: Business, Government, researchers, and the public will experience increased productivity with improved decision making at all levels. This will include high level government policy making, in which optimum choices will be made between the environment and economic growth. Education for all Americans will be improved and business opportunities enhanced, using environmental data as an enabler for entrepreneurs.

NOAA's programs can be effective only if the resulting information products and services are brought in a timely way to the broadest possible range of users in the public and private sectors, education, and in support of academic research.

CURRENT EFFORTS

NOAA is steward for the global environment and describes and predicts changes to the environment. The foundation of this mission is NOAA's ability to deliver products and services to all users.

Build Sustainable Fisheries

NMFS is modernizing its computing and telecommunication capabilities through the Marine Ecological Data System (MEDS) program. MEDS computer procurement will increase computing rates, input, output, and data visualization. With additional capability, NMFS can

expand its ecosystem management for living marine resources. In addition, key data will be rescued and access to NMFS data will be enhanced.

Recover Protected Species

NOAA has created the largest database of protected species for use in plans and actions e.g., Marine Mammal Permitting System, the Stranding Network. The NMFS MEDS modernization program, described above, supports the analysis and use of this information.

Sustain Healthy Coasts

NOAA collects, synthesizes, and distributes information on selected characteristics of coastal and estuarine areas, the distribution of living marine resources, habitats, and economic activities and impacts. The data are being integrated with geographic information and analysis systems to improve their utility for coastal managers.

Advance Short-Term Warning and Forecast Services

A system upgrade is well underway in support of NWS weather forecasting and severe weather warnings. Observing systems have been and are being upgraded, including the new NEXRAD Doppler radar and the Automated Surface Observing System (ASOS). Additional computational capability for predictive modeling and integrated data communication and forecaster displays (AWIPS) are being built. Improvements in dissemination of forecasts and warnings are part of this modernization, for the most part using extensions of traditional telecommunications.

Implement Seasonal to Interannual Climate Forecasts

NOAA's National Data Centers for climatic, oceanographic, and geophysical and solar-terrestrial data are responsible for the long-term care of much of the world's environmental data. Seven world data centers facilitate archiving of these data. Many data compilations and products, i.e., long-term, quality data sets, are relevant to aspects of seasonal-to-interannual climate prediction and assessment. The Satellite Active Archive (SAA) is a prototype system providing on-line access to operational satellite data and products. SAA has inventory, browse, search, order, and delivery capabilities. Targeted prototypes have been developed to provide on-line access to operational data and products from satellites, *in situ* ocean arrays, and land-based meteorological sensors.

Predict and Assess Decadal to Centennial Change

NOAA has a significant role in the U.S. Global Change Research Program (USGCRP), sponsoring and conducting research over a wide range of important global environmental issues. NOAA Climate and Global Change research addresses crucial issues through ocean

and atmospheric modeling. NOAA has the unique responsibility within the Federal Government to monitor, describe, predict, and assess changes in the environment. NOAA works as a partner with EPA, DOE, DOI, DOD, and the other Federal agencies. It is essential to exchange environmental data among agencies and policy makers, educators, industry, and researchers to achieve maximum efficiency in the assessment process.

Promote Safe Navigation

There has been a modest beginning in incorporating digital data in Electronic Chart Display Systems (ECDIS) to produce an integrated set of navigational and environmental information to ships' bridges. NOS will complete modernization of the National Water Level Observation Network and its tidal prediction products/services. Designated by the Federal Geographic Data Committee as the lead agency to supply shoreline, bathymetry and geodetic data, NOS will provide these for coastal zone GISs. NOS intends to establish a network of about 1,300 geodetic reference stations.

NOAA INFORMATION MANAGEMENT PROGRAMS

High Performance Computing and Communications (HPCC)

Advances in the capability to monitor and understand the environment are strongly linked to advances in high performance computing and the algorithm development necessary to exploit computational performance. Our ability to better predict severe weather requires ever-increasing computational power. Our ability to understand climatic change is dependent upon

numerical representation of ocean and atmospheric physics at ever-finer scales. Research in environmental modeling by DOD, DOE, and NOAA, have significantly improved climate predictive capability.

- Because weather warnings, seasonal forecasts, and regional climate predictions depend heavily on computing power, NOAA has begun using scalable architecture, client/server technologies, and massive parallel processing.

- NOAA has a networking/connectivity program to increase its ability to disseminate real-time and historical data over the Internet. The NOAA Internet Network Information Center (NIC), gives NOAA a unified Internet presence and provides information and support to NOAA elements. NOAA has increased its network data dissemination which now routinely exceeds 200 gigabytes per month.

Data System Modernization

- Under the Environmental Services Data and Information Management (ESDIM) program, NOAA supports the rescue and enhancement of many unique data sets and

the development of data management plans. These efforts include digitizing solar data, reprocessing ozone data, analyzing and documenting atmospheric temperature anomalies due to sensor changes, historical shoreline surveys, digitizing California Cooperative Oceanic Fisheries Investigation data; and improved AVHRR, TOVS, and DMSP satellite data inventories.

- ESDIM has sponsored pilot demonstrations to address requirements of modernized NOAA data systems. NOAA facilities in the Pacific Northwest have joined together into a cooperative venture to develop a demonstration campus network for sharing environmental data and information. This integrated, cross line office project enables a broad range of users to access and visualize a rich spectrum of NOAA products using the World Wide Web. MEDS is developing an integrated marine ecological data base. The Management of Atmospheric Data for Evaluation and Research (MADER) has addressed the source-to-user data cycle. Data, products and metadata from the Wind Profiler Network have been made available on Internet.

- NOAAServer System development, which is coordinated within ESDIM, involves each Line Office and the National Data Centers in utilizing WWW technologies to develop a universally accessible, nationally distributed NOAA environmental information system. This prototype information system provides a basic framework within which a rich array of capabilities will be implemented. The core design of this system is an information discovery and retrieval mechanism that allows the user to issue a single query that results in a comprehensive search of distributed information servers. The discovery and retrieval mechanism accommodates the diversity of NOAA information offerings, including imagery, time series data, oceanic and atmospheric profiles, single-point observations, and manuscripts.

- NOAA is presently actively involved in several activities that implement elements of Executive Order 12906 -- Coordinating Geographic Data Acquisition and Access, the National Spatial Data Infrastructure. The order directs all Federal agencies to contribute to the development of the National Spatial Data Infrastructure (NSDI). NOAA efforts include: Developing data collection and content standards for several types of geospatial data; implementing the NSDI metadata standard for all of NOAA's data holdings; contributing to the NSDI Clearinghouse; building data bases for geographic information systems (GIS); implementing the Spatial Data Transfer Standard (SDTS); and initiating pilot studies in order to test various issues facing the development of the NSDI.

World Wide Web Technologies

World Wide Web (WWW) technologies, recently introduced into NOAA, hold the promise of revolutionizing NOAA's delivery of information services to the Nation. They allow the user to access a vast range of multimedia information, including graphical color displays,

through a simple point-and-click desktop environment. Many organizations in NOAA have utilized these technologies to more effectively reach their user communities. An important side-benefit of providing these services via the publicly available Internet has been the expansion of NOAA's information services far beyond its traditional client community. More then 200 "Home Pages" belonging to NOAA organizations can now be found on the WWW.

Administration

To implement the Strategic Plan, NOAA must have efficient administration. Inefficient, time-consuming, and internally uncommunicative elements make success more difficult.

- NOAA's existing administration is primarily paper-based. Forms are typed and sequentially processed. Each step is preceded by delays associated with moving paper between offices. Data from forms are entered into several official, "cuff" data bases, each serving a limited audience and requiring maintenance and support staffs.

- Although about 80 percent of NOAA employees have access to electronic mail, systems often are not connected, are difficult to maintain, unreliable, or difficult to use.

FURTHER EFFORTS NEEDED

NOAA's current environmental information services are driven by history and circumstance. Specific dissemination systems have been placed into operation as opportunities have arisen and as demand for specific data and information products has grown.

Insufficient Access to Data

NOAA products are now disseminated only on a limited basis, largely in response to requests. Real-time data are sometimes delayed; historical data can take months to be retrieved and/or published. Environmental information is not integrated with other NOAA data or with data from other DOC or Federal agencies having environmental programs. The accuracy and reliability of NOAA's products are limited by computer performance. Despite recent efforts to use public-domain software newly available on the Internet, NOAA's current capability is limited due to a lack of resources. This is a barrier to timely dissemination of the products.

Outdated Data and Computational Technology

New observing technologies with vastly increased volume and speed, threaten NOAA's ability to integrate data into useable products and distribute them. Much greater computing power and network connectivity are needed.

Improvements in numerical weather forecasts and climate prediction are closely tied to advances in high-end computers. While today's models and super-computers are tremendous advances from a decade ago, global models still lack key features, such as weather fronts and ocean eddies, and distort others, such as clouds and intense convection.

Existing NOAA Data Not Exploited

The need for environmental data continues to increase exponentially. Satellites are producing massive amounts of data that NOAA should process, analyze, archive, and disseminate.

NOAA is responsible for the initial analysis, use, and archiving of data from meteorological satellites, GOES, polar-orbiting environmental satellites, and new surface-based systems, such as NEXRAD, Wind Profilers, and Automated Surface Observing System. NOAA is responsible for analyzing and archiving data from the Global Ocean Observing System (GOOS). NOAA will archive and disseminate data from NASA's Earth Observing System (EOS).

Need to Modernize NOAA's Data System

NOAA's information delivery must appear unified and integrated even though practical requirements within NOAA and other agencies mandate that data be acquired and stored in many places. An integrated information system for thousands of users is critical to U.S. economic competitiveness and sound environmental policy. Data bases covering specific and multiple disciplines and one or many countries must be brought together. The system must fully exploit the Internet and its successors.

PROPOSED ACTIONS

Build Sustainable Fisheries

MEDS is an integrated marine ecological data base supporting management of living marine resources and monitoring the health of ecosystems. As such, it provides a testbed for a distributed data system with broad data coverage, but with clearly identified and focused management uses. This outstanding platform can test many concepts that will eventually be extended to the rest of NOAA and the Nation.

Recover Protected Species

Under MEDS, there are efforts to build or expand high priority data bases to support management obligations under the Marine Mammal Protection Act and the Endangered Species Act, e.g., Marine Mammal Exemption Program and the Stranding Network.

Sustain Healthy Coasts

More information must be acquired on the structure and dynamics of marine ecology. This information can be used in planning and management. Investments in enhanced GIS systems for coastal and living marine resources are integral to this.

Monitoring information for coastal zone managers can be made available electronically in a more timely manner than it is today. If layers of a Geographic Information System (GIS) are updated electronically, coastal zone managers can update their databases, e.g., environmental quality assessment updates (near real-time health of the coast) and blends of census and land use data.

Advance Short-Term Warning and Forecast Services

Data streams from GOES, polar orbiting satellites (POES), NEXRAD, and next generation GOES must be captured, processed, archived, and made available in near real-time. NOAA POES provides data to support improved weather prediction and global environmental monitoring. The next-generation GOES archive will be twice the size of the current archive. NEXRAD, which will require automatic quality control of 71-100 terabytes per year, will be the world's largest single source of environmental data when it becomes fully operational in 1997. A path to these data sets, which will be in great demand, needs to be identified. Concept demonstrations will address options for handling large data sets (e.g., ingest, archiving, access, information management).

AWIPS, an advanced computer/telecommunication system, will allow forecasters access to large volumes of observations from a variety of observing systems, including NEXRAD, ASOS, Wind Profiler, satellites, aircraft, cooperative observers and buoys. AWIPS will integrate these with advanced atmospheric models of the National Centers for Environmental Prediction (NCEP). NOAAPORT will be the direct satellite broadcast link for AWIPS products and services to NOAA and non-NOAA users. NOAA researchers will have access to the latest model guidance and world-wide observations. Additionally, the FAA, DOT, and DOD will benefit from improved aviation and marine forecasts and the private sector from access to more data and products.

Advanced numerical assimilation and forecast models require more frequent and closely spaced wind, temperature, and moisture data than are available today. Within a few years, NOAA must implement an improved observing system, if the promise of improved guidance is to be realized. Systems to provide these data have been under development by NOAA, including improved radiosondes, wind profilers, automated aircraft observations (ACARS), Radio Acoustic Sounding System (RASS) temperature profilers, and satellites. Appropriate data management and archive procedures for each test bed data set will be established and implemented.

The Automated Surface Observing System records 5-minute observations and 1-minute engineering data, which are sent to the National Climatic Data Center (NCDC) for archiving. The high-resolution precipitation accumulation, wind, and pressure data can support advanced mesoscale applications and research. Archival and management of these data will be critical, as ASOS has been installed and accepted at over 650 U.S. sites.

Implement Seasonal to Interannual Climate Forecasts

The Satellite Active Archive (SAA) will be tested through participation in various studies such as GEWEX/GCIP. SAA will provide on-line access to data, which will allow for reprocessing long-term data sets as improved algorithms and calibration information become available. The SAA is also the NOAA gateway to NASA's Earth Observing System Data and Information System (EOSDIS).

A key element of the NII, cited in the National Performance Review, is development of a National Environmental Data Index (NEDI) to allow citizens, industry, and academia access to government environmental data, in accordance with OMB Circular A-130. This avoids duplication by the government and provides a starting point for all users.

The execution of large, complex models, such as those for the coupled ocean-atmosphere, produces large volumes of data. These must be analyzed, shared within NOAA and externally, and compared to other models' data. Running a model can produce up to four terabytes of data; much needs to be stored and processed over months or years.

The NCEP/NCAR Reanalysis Project will continue to produce one of the most important data sets for climate research to support improved medium-range and longer-range forecasts. The NWS will need to maintain computational resources to continue to produce this critical data set over the coming years. NCDC, NCAR, and OAR's Climate Diagnostics Center participate in the archiving and redistribution of this data set. The Climate Diagnostics Center is a redistribution point for this data set within NOAA and for NOAA's scientific collaborators.

The NOAA-NASA Pathfinder project, as it completes reprocessing historical satellite data, provides the foundation for further data base and product development. This work will provide the capability to integrate, produce and distribute NOAA climate products, blending remotely sensed and *in situ* data. Retrospective data can be used for validation; operational data to initialize and update forecasts.

Predict and Assess Decadal to Centennial Change

Several pilot projects will be targeted to specific users and designed to exploit and evaluate the new data access support tools. Among the candidates are:

- A National Earth Watch Service with rapid network interactive access to enhance information that is relevant primarily to policy makers is required to assure that environmental, economic, technical data are available in a format that is usable for regulators and decision makers.

- The planning and implementation of the Global Change Data and Information System (GCDIS) is a multi-agency, and ultimately international, effort to facilitate access for researchers and others to global change data and information as part of the U.S. Global Change Research Program (USGCRP). Key objectives include: (1) provide users all priority data and information regardless of source or type, (2) develop the capability to view and take electronic delivery of all data managed under GCDIS through access to any single agency system.

- Data from NOAA's National Data Centers and many of its centers of data must be made accessible to NASA Earth Observing System (EOS) researchers, as a part of the GCDIS. Additionally, NOAA will provide the long-term archive for data produced by EOS. The options for operating such a data archive are only beginning to be analyzed and costed. The Global Ocean Observing System (GOOS) will address long range problems associated with climate and biogeochemical cycles; NOAA will be responsible for archiving these data.

- The identification of critical climate trends has been compromised by inadequate measurements or inadequate data processing/archiving. With modest improvements to our existing weather watch network and data management systems, we can ensure early detection of climate change. Components of this system include the operational satellites, the cooperative weather observing network, and the upper air network.

Promote Safe Navigation

NOS will improve the versatility of its nautical chart data by adding the capability to deliver these data in multiple formats, including digital data for electronic charts. The goal is to automate within five years. Meanwhile, data base management systems will be implemented to provide products for GIS users. NOS will create a digital aeronautical chart data base able to receive new information and provide access to navigational information.

NOS will complete installation of the National Water Level Observation Network, providing real-time tide and current data in ten major ports and digital tide prediction products for five major estuaries. The goal is marine forecasting capability in five years.

Through cooperative arrangements with the states, NOS will establish and manage data from the Federal Base Network of monumented reference stations.

NOAA INFORMATION MANAGEMENT CROSS-CUT PROGRAMS

High Performance Computing and Communications

Emerging computing and communication technologies provide benefits to all programs and functions of NOAA. In particular, the World Wide Web provide a significant increase in our ability to communicate NOAA information within NOAA and to our national and international customer base. These technologies support our administrative and business processes as well as our seven strategic elements. High performance computing is essential to the NOAA mission to model and predict the behavior of natural systems, including weather, climate, and fisheries. Collectively, these strategic tools are critical to fulfilling our mission:

- NOAA will improve global access to its diverse, real-time, environmental data and information and advanced computational facilities through greatly improved Internet connectivity, including NOAA's National Data Centers and over 30 centers of data.

- NOAA-wide Internet connectivity will be achieved through Internet Regions, where each region has a designated campus Hub. Selected regions correspond to locations containing concentrations of NOAA environmental data, people, and information technology, aiming at network integration across Line Offices. The immediate focus is on campuses, such as the Boulder complex, the Silver Spring Metro Center facilities, the Seattle components, and the Miami facilities.

- NOAA will begin to exploit the scalable architecture computing systems for weather and climate prediction and for reanalysis of historical observations. NOAA has begun a phased acquisition of high performance computer systems with scalable computing capabilities at its most important computer centers. This acquisition has been coupled with the conversion of major numerical models to utilize the parallel processing paradigm of the new technology systems.

- NOAA will evaluate the potential use of advanced, high performance computer architectures for improving access to massive data bases. Massively parallel processing (MPP) systems have the potential of conducting multiple searches through large databases in parallel thereby greatly decreasing search and access times.

Data System Modernization

NOAA will build on a pilot effort initiated in FY 1993 to create a national virtual environmental data base by making use of current data base concepts and client-server technologies across a wide-area network. The implementation of a virtual data base across the geographically dispersed NOAA data holdings will begin with the National Data Centers and eventually allow any user to access any data element in a totally transparent way without

regard to data base organization or physical location, while continuing one-on-one specialized service within each data discipline. The resulting virtual data system will present a unified interface to NOAA's customers for one-stop shopping of NOAA data and products.

The NOAAServer System will be extended to other WWW servers across NOAA to provide users a unified, "common look-and-feel" access to a wide range of NOAA information services. Overall system capabilities will be enhanced by the periodic insertion of new WWW technologies, such as Java servers and clients, to create a highly dynamic interactive user environment. Visualization, subsetting, and data fusion tools will be developed and implemented.

The NOAA ships and aircraft need to be connected to NOAA National Data Centers and centers of data to provide uploading of remote sensing and in situ data and downloading of extensive environmental data sets, data models, and imagery data to facilitate efficient platform-based or shore-based research by the scientific community. This involves implementation of ship-to-shore technology aboard the scientific platforms, requiring a network capable of high-speed connections for data transfer between remote platforms, including ships, aircraft, and other automated platforms, and the multiple NOAA data centers. This requires a shore-based facility/function, a platform-based support function, and a high-speed and cost effective data link.

In order to support the expanding community of Geographic Information Systems (GIS) customers, NOAA will expand its activities in support of the National Spatial Data Infrastructure (NSDI). This will include working with other Federal, state and local agencies and the private sector to ensure that data standards are developed to encourage sharing and cooperative collection of geospatial data. In addition, NOAA will be fully connected with the NSDI data clearinghouse through the implementation of the metadata standard. Working closely with the customer community, NOAA will develop data bases that are designed to support the wide range of GIS applications and will have these data available for distribution in the Federal standard for spatial data (FIPS 173). Working with State and local communities, regional pilot projects will be designed to serve the immediate needs of users within a local community. NOAA will establish a GIS support infrastructure in order to facilitate the infusion of this technology into the workforce.

World Wide Web Technologies

NOAA must encourage the rapid deployment of WWW technologies to meet its information dissemination needs. These technologies reach a far wider audience than other means at our disposal, and in effect, place the organization's data and information databases in the broad context of national and international environmental information databases. NOAA must place a "corporate face" on these rapidly growing information offerings available via the WWW.

- NOAA will coordinate its WWW "Home Pages" to ensure information content is current and accurate and that electronic software links are maintained among the information servers.

- NOAA will develop a set of guidelines for style and content to create a NOAA "corporate presence" on the WWW.

- NOAA will sponsor conferences and workshops (e.g., WebShop '95) and promote the establishment of developers groups to encourage the exchange of information in today's highly dynamic WWW technologies environment.

Administration

NOAA is planning to have modern, efficient administrative systems that will support the successful implementation of the NOAA Strategic Plan.

- Commerce Administrative Management System (CAMS) - NOAA's long term strategy is to use the DOC-wide CAMS system with its various subsystems as the basis for a modernized and re-engineered administrative processing system.

- Electronic Commerce (EC) - On both a short-term and long-term basis EC will be used to improve both internal processes and external relationships with business partners. This includes forms automation, electronic transmission of forms and dissemination of business information, and full electronic data interchange with business partners.

- Electronic Mail - Standardized electronic mail hubs with common directories will be established so that electronic mail can be easily and reliably sent to all NOAA organizations.

Integrate Support to All NOAA Strategic Elements

All the above efforts offer critical support to NOAA strategic elements. In addition, however, planning and coordination are being carried out across strategic elements, NOAA Line Offices, NOAA Program Offices, and NOAA Staff Offices. This across-the-board planning should avoid duplication and maximize efficiency through agreement to standards. The result will be the appropriate emphasis and follow-through within individual strategic elements of the four information service activities: (1) establishing sufficient access to data; (2) updating technology; (3) exploiting NOAA data; and (4) modernizing NOAA's computing, communications and data systems.

SUPPORTING INFRASTRUCTURE

OVERVIEW

The Strategic Plan identifies challenges facing NOAA over the next months and years. To meet them, NOAA must ensure excellence in its work force and facilities, educate the public on its research and management concepts, and provide administrative support for NOAA's program offices. These functions, collectively termed the *Supporting Infrastructure*, are education, the NOAA work force, facilities and administrative services.

Supporting Infrastructure is vital to sustain NOAA and to support NOAA's programs. Indirectly, it serves many constituencies besides the Commerce Department (DOC), including other agencies of the executive branch, the legislative and judicial branches, state and local governments, academia, and the private sector.

CAPABILITIES

EDUCATION

Education transfers information to targeted audiences; outreach provides the public a glimpse of NOAA's efforts; and both help NOAA achieve its goals and objectives. NOAA's researchers and managers provide findings and requirements to its education and outreach staff. This staff, in turn, is able to call on a strong external network to reach NOAA's constituents, including the general public. NOAA has specific legislative mandates for education, including, the National Estuarine Research Reserves System in the Coastal Zone Management Act; the National Marine Sanctuaries Program in the Marine Protection, Research and Sanctuary Act; and the National Sea Grant College Program [Act]. A few examples demonstrating how NOAA uses education and outreach include:

- developing and distributing brochures explaining particular programs, projects, and services;

- targeting key audiences and providing them with instruction on earth systems and on how to avoid damaging the environment; for example, NOAA could offer classes for boaters on reading navigational charts and using established mooring buoys to prevent reef damage; and

- training secondary school teachers in ecosystem management.

NOAA WORK FORCE

NOAA's tasks are accomplished by a variety of professionals and technicians, including meteorologists, hydrologists, cartographers, oceanographers, fishery managers, physicists,

computer scientists, engineers, technicians, law enforcement agents, support personnel, and so on. These employees are stationed worldwide on ships, aircraft and undersea habitats, and at laboratories and weather stations. They use personal computer workstations, some of the world's most powerful computers, and geostationary and polar observational satellites. The NOAA family even embraces broad sectors of the general public. Researchers in academia, volunteers collecting weather data, and members of power boat squadrons updating nautical charts, all of these people and many more besides, make substantial contributions to the accomplishment of NOAA's mission.

FACILITIES

NOAA headquarters and its field installations are major national assets, and they are fundamental to the accomplishment of NOAA's mission. NOAA facilities, found in every state and territory, include remote observatories, office buildings, and NWS offices. Pre-eminent are 41 specialized laboratories belonging to the National Marine Fisheries Service and the Office of Oceanic and Atmospheric Research. NOAA owns 298 installations. The condition of its 614 buildings (median age over 30 years) ranges from new to well-maintained to deteriorating.

NOAA must provide safe, healthful facilities that comply with state and local regulations; that are in good repair and run efficiently; and that are in locations that support and enhance agency missions. NOAA maintains its high-priority facilities while establishing the capability to make improvements elsewhere. Eventually, NOAA will have facilities requiring only routine maintenance and replacements.

ADMINISTRATIVE SERVICES

NOAA provides its programs and employees with a wide range of administrative services; these include payroll and personnel systems, real property and space management, personal property management including warehouses, civil rights, procurement, small purchases, grants, finance, administrative payments, publications, systems support, telecommunications, health, safety, security, recycling, mail management, vehicle fleet management, and logistics. The NOAA Office of Administration supports approximately 4,300 employees in the National Capital Region, mostly in Silver Spring, MD. Beyond the National Capital Region, NOAA supports the balance of its employees, the employees of other DOC field components, and some employees of other federal agencies. This field support is provided by four Administrative Support Centers, located in Seattle, Washington; Boulder, Colorado; Kansas City, Missouri; and Norfolk, Virginia.

Other NOAA offices provide administrative support. The Office of the Comptroller manages the NOAA budget; the Systems Acquisition Office supports major procurement; and the National Data Buoy Center supports its own specialized purchasing.

CURRENT EFFORTS

EDUCATION

Education and outreach are valuable in fulfilling NOAA's mission, and a number of offices and programs are engaged in developing and implementing different education and outreach activities. These efforts are decentralized because NOAA targets different audiences, including: primary and secondary school teachers; undergraduate, graduate, engineering and policy students; adults whose livelihoods are linked to NOAA's missions, such as resource planners, coastal developers, and commercial fishers; and the general public.

NOAA conducts its strongest efforts at the regional and state levels, in partnership with government agencies, tribal organizations, industry, non-profit organizations, academia, libraries, museums and community organizations. A few examples of NOAA education and outreach efforts include:

- Operation Pathfinder, a nationally coordinated regional summer graduate course on oceanography and coastal processes for teachers of minority students. It addresses fishery management, protected species, coastal ecology, and climate change. It is funded by the Office of Oceanic and Atmospheric Research, the National Environmental Satellite Data, and Information Service and other federal agencies and sponsored by Sea Grant regional programs.

- The Global Change Education Workshop, a nationally coordinated, regional workshop for informal educators. It covers climate forecasting and global environmental change. The workshop is funded by the Office of Global Programs, and sponsored by Sea Grant regional programs.

- The annual Satellites in Education Conference, supported by NESDIS for professional educators, discusses uses of satellite imagery in the classroom. Its goal is to promote science and technology among students.

- Nonpoint Pollution Control Outreach, a national program funded by the National Ocean Service Office of Ocean and Coastal Resource Management, provides policy and technical information to state officials in support of state antipollution programs. Included are regional workshops on the impacts of land uses, such as forest harvesting, dairy operation, and golf courses on coastal ecosystems and water quality.

- *Waterways*, a weekly television program, is produced by the Florida Keys National Marine Sanctuary and presents timely management issues, education, and research. It is broadcasted statewide and reaches many who use Florida's coastal and marine environments.

- The Dean John A. Knauss Fellowship, supported by Sea Grant, allows students to do research in oceanography, meteorology, and policy.

- Project Atmosphere, two weeks of training in weather forecasting for teachers, is conducted by the American Meteorological Society and funded by the National Weather Service.

These activities are undertaken to educate the public, and hopefully, foster an understanding of and support for NOAA's strategic goals. Education is also a key element for ensuring that NOAA will have the supply of culturally diverse, trained individuals it needs to continue its dual mission of environmental stewardship and environmental prediction and assessment.

WORK FORCE

NOAA is responding aggressively to the challenging demands of the Work Force Reduction Act of 1994 and the National Performance Review.

The Work Force Reduction Act mandates a staff reduction of approximately 2400 full-time equivalents by FY 1999.

To reduce staffing, NOAA seeks to increase the rate of attrition while minimizing mission degradation. Towards this purpose, NOAA has:

- Imposed employment freezes;

- Implemented staffing reductions;

- Offered buy-outs through the Voluntary Separation Incentive program;

- Offered early retirements to foster attrition; and

- Planned a placement process for employees affected by programmed reductions.

To ensure the reduced work force is capable of accomplishing its mission, NOAA has:

- Established a diversity council, with the support and participation of its leadership, to develop plans for including all sectors of the population in NOAA's future work force;

- Established a diversity recruitment coordinator;

- Held diversity training for senior executives, and scheduled it for middle management; and

- Allocated an amount equal to 1.5 percent of salary expense to fund employee training and development.

The National Performance Review has the goal of "reinventing government," which mandates reducing regulations and improving processes. For its part in this effort, NOAA has:

- Conducted numerous customer surveys to identify which products and services need improvement;
- Developed customer service plans to make the improvements identified through the surveys;
- Aggressively sought suggestions from its workers and constituents to streamline operations;
- Implemented DOC and NOAA suggestions on reinventing government; and
- Reduced administrative orders by more than half.

FACILITIES

NOAA must assure that the condition, configuration, and location of its facilities adequately support its mission. NOAA's strategic planning assumes its staff can work safely and effectively at the forefront of science and technology. A failure to provide safe, healthful, and legal facilities might initially degrade mission effectiveness only. If left unresolved, however, it can eventually jeopardize NOAA's ability to function.

Repairs and Renovations: A program to repair and renovate NOAA's 614 owned buildings NOAA is now in its fourth year. The program is defined, a format for the project prospectus now exists, facility condition surveys are underway, and the backlog of priority projects is being tracked.

Environmental Compliance: NOAA must ensure environmental compliance at its facilities. Funding is limited and only projects with compliance deadlines or emergency cleanups have been supported. The current backlog has been compiled, but a comprehensive picture will not be available until scheduled environmental compliance audits and surveys are completed.

New Construction: NOAA has a number of construction projects in various stages of progress that are essential to NOAA's mission. These projects include:

- The NOAA Center for Coastal Ecosystem Health at Charleston, South Carolina;

- The NOAA environmental research laboratories at Boulder, Colorado;
- The NOAA operations and research center at the NASA-Goddard Space Flight Center (in planning);
- The relocation of the National Marine Fisheries Service Tiburon Laboratory to Santa Cruz, California;
- The consolidation of NMFS at Auke Cape, Alaska; and
- There are multi-agency projects for joint-use federal/state facilities underway at Fort Johnson, South Carolina; Oxford, Maryland; and Lafayette, Louisiana.

ADMINISTRATIVE SERVICES

Like its work force and facilities, NOAA's administrative services support every NOAA activity. The examples which follow highlight a few of the activities now underway.

- Financial assistance and procurement, ⅓ of the budget, includes that spent directly, contracts or grants approved for spending, and rent or vehicles that are monitored and managed. These commitments constitute investments directly or indirectly serving NOAA's mission. Through its hundreds of grants and tens of thousands of procurement, NOAA invests in states, communities, universities, and industry.
- NOAA's Information Resources Management staff continue efforts to improve electronic communication, including managing electronic communication at the Silver Spring campus and gateway communication between different systems.
- NOAA has revamped its Administrative Order Series in line with DOC guidance, reducing it by more than half. This work directly implements the Vice President's reinventing government.
- NOAA's Human Resources Management Office is reorganizing its structure and staffing levels.
- NOAA is developing a strategy for work force diversity. NOAA believes that a diverse work force is best for accomplishing its goals and objectives.
- Like many organizations, NOAA links its systems and computing functions with finance operations. NOAA is working closely with the DOC to develop the Commerce Administrative Management System (CAMS), a major tool for managing resources in the entire DOC, including NOAA.

FURTHER EFFORTS NEEDED

EDUCATION

Despite its current efforts, NOAA needs stronger, more integrated educational programs, because:

- NOAA is facing a growing public demand for products and services related to the daily impact and broader economic effects of the oceans, coastal waters and atmosphere.
- Demographics are changing, and there are population sectors that NOAA has not reached. NOAA will need to reach them.
- As a steward of federal investments, NOAA must ensure the best possible return on its investments. Continuing and improving NOAA's education and outreach efforts is a basic component to this role.

WORK FORCE

NOAA will face a number of challenges associated with its work force. Downsizing, the aging of the work force, changing demographics, austere budgets, and increasing responsibilities represent long-term risks to NOAA's work force and its ability to function. NOAA must take steps to reduce these risks to ensure the continued vitality of this resource.

FACILITIES

Repairs and Renovation: Proper facility maintenance is unending by its nature. Deferring maintenance or delaying equipment replacement accelerates deterioration, decreases asset value, increases the risk of building or equipment failure, and raises replacement costs.

Environmental Compliance: NOAA is required by statute, executive orders, and Departmental administrative order to conduct an environmental compliance program. Environmental problems at NOAA installations are continually being discovered. Such problems must be swiftly corrected since discovery legally mandates a compliance deadline. Failure to comply carries personal, civil, and criminal liabilities for NOAA's managers.

New Construction: NOAA is starting to realize the benefits of the Silver Spring, Maryland headquarters consolidation project. A NOAA corporate identity is emerging, and the exchange of scientific data and information across organizational lines has been enhanced. Continuing initiatives, such as Silver Spring and Boulder, ensure that NOAA's facilities keep pace with its needs.

ADMINISTRATIVE SERVICES

Although technology helps, administrative services remain labor intensive. In the next ten years, the administrative services work force will experience significant turnover, largely due to retirements. American demographics are changing, and NOAA has the opportunity to develop diversity strategies to recruit new employees from all sectors of the population.

The federal government is also changing, and many job definitions will change as the goals and objectives of the National Performance Review are realized. Advances in computers, communications, and other technologies will change the way NOAA works. Administrative services must take advantage of these technologies.

PROPOSED ACTIONS

EDUCATION

The actions proposed below are consistent with our decentralized approach to education.

- Include education and outreach efforts to achieve management goals;
- Ensure NOAA's outreach efforts are consistent in making NOAA a source for information, data and training;
- Expand use of computer technologies and telecommunication to link targeted audiences with NOAA's education efforts; and
- Combine efforts and resources among NOAA elements conducting education and outreach, for the greatest return on investment.

WORK FORCE

NOAA will demand more from its remaining employees and greatly emphasize employee training and development. NOAA will maintain and enhance educational outreach programs that develop interest in science among young people. NOAA must continue education and training for all age and educational levels. These efforts should lead to a better prepared talent pool and increased interest in working for NOAA.

NOAA will institute an out-placement program for employees affected by reductions-in-force. A DOC OHRM employee will serve as out-placement coordinator, working with personnel offices to identify local support organizations, contract for employee job counseling, and develop sources of funds for out-placement efforts in line and staff offices.

Despite downsizing, NOAA will protect cooperative student programs to enhance access to the new work force. NOAA will increase cooperative relationships with universities and other research institutions.

FACILITIES

Repairs and Renovations: NOAA will continue to: conduct facility condition surveys; undertake major repairs, alterations, upgrades, and renovations; perform maintenance; make multi-year improvements to installations owned by NOAA; and invest in energy conservation.

Environmental Compliance: In regard to environmental problems, NOAA proposes to prevent new problems, to identify existing problems and correct them, and to clean and restore affected sites.

Planning: NOAA will identify changing facility requirements, coordinate planning major new installations, and integrate them into existing facilities.

ADMINISTRATIVE SERVICES

A new organizational structure for administrative services will be defined. It will reflect the philosophy of the National Performance Review and be based on technology, to compensate for staff losses.

APPENDICES

APPENDIX A

ORGANIZATION CHART

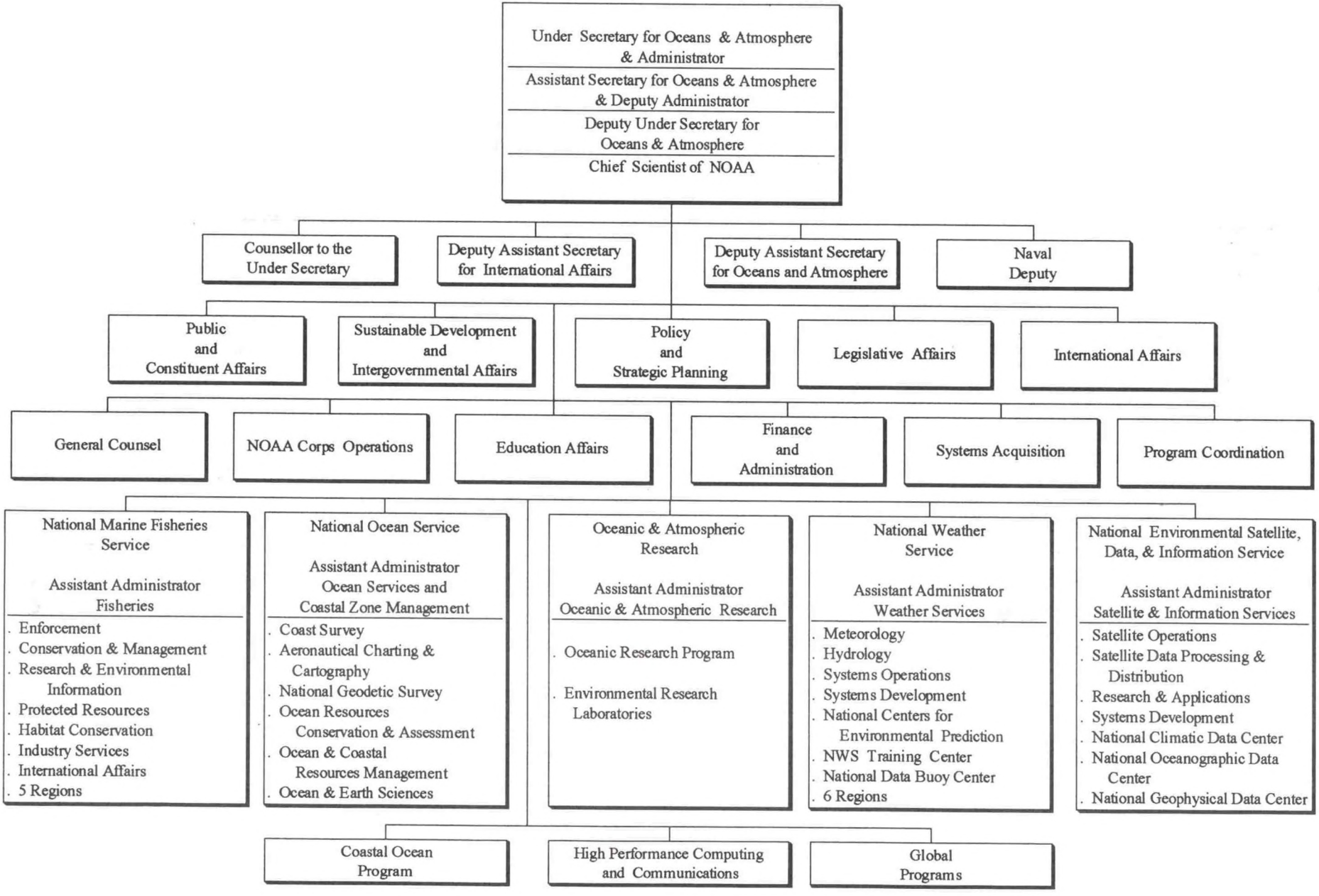
OF THE

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Prepared by HRMO

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION

NOA-9511
Exhibit 1 to
DOO 25-5



APPENDIX B

STRATEGIC PLAN TEAMS

ADVANCE SHORT-TERM WARNING AND FORECAST SERVICES

Boezi, Lou (NWS) Team Leader

Aikman, Frank (NOS)
Baker, Wayman (NWS)
Beran, Don (OAR)
Blackmore, Bill (NWS)
Boothe, Bud (NESDIS)
Bower, Carl (NWS)
Gray, Judy (COP)
Hooke, Bill (OAR)
Ingram, John (NWS)
Jalickee, John (NWS)
Klingensmith, Larry (NWS)
Laws, Earl (NWS)
McCalla, Margaret (PSP)
Miller, Chuck (BF4)
Morris, Roger (ONCO)
Namian, Doug (NESDIS)
Przywarty, Rich (NWS)
Rasmussen, Jim (OAR)
Sargeant, Doug (NWS)
Thomas, Rich (NWS)

IMPLEMENT SEASONAL TO INTERANNUAL CLIMATE FORECASTS

Leetma, Ants (NWS) Team Leader

Arkin, Phil (NWS)
Gruber, Arnie (NESDIS)
Mairs, Rob (NESDIS)
Miller, Chris (NESDIS)
Miller, Laury (NOS)
Mooney, Ken (OGP)
Mulhern, Marty (ONCO)
Mulligan, Pat (PSP)
Nierenberg, Claudia (OGP)
Patterson, Mike (OGP)
Peterson, Bill (NMFS)
Piotrowicz, Steve (OAR)
Quigley, Mike (PCO)
Ray, Andrea (PSP)
Woodward, Bill (NOS)

PREDICT AND ASSESS DECADAL TO CENTENNIAL CHANGE

Albritton, Dan (OAR) Team Leader
Goodrich, Dave (OGP) Team Leader

Arkin, Phil (NWS/NMC)
Jones, Ken (MB liaison)
Karl, Tom (NESDIS/NCDC)
Leffler, Bob (NWS/OSO)
Mahlman, Jerry (OAR/GFDL)
Miller, Chris (NESDIS/EI)
Mulhern, Marty (ONCO)
Ohring, George (NESDIS/RA)
Peterson, Bill (NMFS)
Piotrowicz, Steve (OAR)
Quigley, Mike (PCO)
Ray, Andrea (PSP)
Stein, David (OAR/NURP)
Woodward, Bill (NOS)

PROMOTE SAFE NAVIGATION

Pryor, Don (NOS) Team Leader

Anderson, Alan (NC)
Carter, Bill (NOS)
Challstrom, Charlie (NOS)
Cushing, Linda (NOS)

Faigin, Marty (NOS)
Gross, Chuck (NESDIS)
Leach, Mary (PCO)
Kolf, Dick (OAR)
MacFarland, Dave (NOS)
Russin, Gene (NOS)
Welch, Marty (PSP)

BUILD SUSTAINABLE FISHERIES

Holliday, Mark (NMFS) Team Leader

Bortniak, John (NC)
Callendar, Russell (OAR)
Dowgiallo, Michael (NCOPO)
Fritz, Eugene (OAR)
Greene, Roseanne (SD)
Hughes, Kent (NESDIS)
Marshall, Curt (PSP)
Olivere, Peter (BF4)
Sissenwine, Mike (NMFS)
Swartz, Steven (NMFS)

RECOVER PROTECTED SPECIES

Montanio, Patricia (NMFS) Team Leader

Kaufman, Herb (NMFS)
Snipes, Christopher (NMFS)
Williams, Phil (PSP)

SUSTAIN HEALTHY COASTS

Benoit, Jeff (NOS) Team Leader

Banahan, Susan (COP)
Beeton, Al (OAR/GLERL)
Broutman, Marlene (LA)
Brown, Dail (NMFS)
Burgess, Jim (NMFS)
Butler, Lou (NOS)
Cammen, Leon (OAR)
Cope, Gene (COASTAL AMERICA)
Denning, Elaine (COMP)
Eakin, Mark (OGP)
Faigin, Marty (NOS/MB)
Feden, Robert H. (NESDIS)
Greene, Rosanne (SD)
Griffis, Roger (PSP)
Hess, Kurt (NOS/OES)
Hughes, Kent (NESDIS)
Leach, Mary (PCO)
Lopez, Ralph (NMFS)
Magnuson, Gary (NOS)
Mason, Curt (NOS/CCEH)
Mayer, Gary (NMFS/DARP)
McGilvray, Laurie (NOS)
Myers, Ed (OAR/ERL)
Obrien, Mary (GC/GCOS)
Paterson, Arthur (IA)
Pierce, Theresa (NWS)
Pugh, Larry (COP)
Scholz, Paul (NOS/CCEH)
Shreiber, Ramona (NMFS)
Stein, David (OAR/NURP)
Taylor, Bob (NC)
Uravitch, Joe (NOS)
Sopher, Harriet (NOS)

RESEARCH

Sullivan, Kathryn (NOAA Chief Scientist)
Team Leader

Briscoe, Mel (NOS)
Calder, John (OAR)
Collins, Maggie (NOAA/CS)
Evans, Dave (NOS)
Howard, Ed (SPO)
Johnson, Dave (COP)
Rao, Krishna (NESDIS)
Ray, Andrea (PSP)
Rootes, Becky (NMFS)
Sargeant, Doug (NWS)
Sissenwine, Mike (NMFS)

OBSERVING SYSTEMS

Maloney, Frank (NOS) Team Leader
Nortup, Don (NESDIS) Team Leader

Armstrong, Andy (NOS)
Banahan, Susan (COP)
Cobb, Nanct (OA)
Chertok, Beth (OAR)
Hawkins, Jamison (NESDIS)
Klein, Fred (ND)
Morris, Roger (NC)
Mulligan, Pat PSP)
Murray, Bill (OGP)
Reeves, Bob (NOS)
Roe, Dick (NMFS)
Russin, Eugene (NOS)
Sarb, James (NMFS)
Spillman, Don (NC)
Woodward, William (NOS)
Zbar, Frederick (NWS)

ENVIRONMENTAL DATA AND INFORMATION SERVICES

Withee, Greg (NESDIS) Team Leader

Mulligan, Pat (PSP)
Williams, Phil (PSP)

SUPPORTING INFRASTRUCTURE

Humphries, Don (OA) Team Leader

Abbott, John (OA)
Beattie, Janice (NESDIS)
Beers, Charles (OA)
Fasick, Bob (OA)
Gardner, Richard (OA)
Gird, Ron (NWS)
Grimmett, Howard (OA)
Kirch, Herb (PSP)
Hostetler, Colby (OA)
McKean, Joan (EA)
Remer, Stewart (OA)
Spence, Lundie (OAR)
Szigety, Ken (PCO)
Wilmont, Maureen (NOS)

APPENDIX C

ACRONYM LIST

AAS	Advanced Automation System
ADEOS	Advanced Earth Observing System
AFGWC	Air Force Global Weather Center
AID	Agency for International Development
ALSP	Atmosphere and Land Surface Processes
AMS	American Meteorological Society
ANCS-II	Automated Nautical Charting System
ARPA	Advanced Research Projects Agency
ASC	Administrative Support Center
ASOS	Automated Surface Observing System
ASTC	Association of Science and Technology Centers
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AWIPS	Advanced Weather Interactive Processing System
BF4	Office of Comptroller, Program Planning & Analysis Division
C&GC	Climate and Global Change Program
CAC	Climate Analysis Center
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CCAMLR	Convention of the Conservation of Antarctic Marine Living Resources
CEES	Committee on Earth and Environmental Sciences
CENR	Committee on Environment and Natural Resources
CEOS	Committee on Earth Observation Satellites
CEP	Caribbean Environment Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFCs	chlorofluorocarbons
CICS	Cooperative Institute for Climate Studies
CINTEX	Catalogue Interoperability Experiment
CITES	Convention on International Trade in Endangered Species
CLIVAR	Climate Variability (Program)
CMDL	Climate Monitoring and Diagnostic Laboratory
CMP	Coastal Management Programs
CNES	Centre National d'Etudes Spatiales
COE	Corps of Engineers
COMET	Cooperative Operational Meteorological Education and Training
COP	Coastal Ocean Program
CPC	Climate Prediction Center
CS	Chief Scientist
CZM	Coastal Zone Management
DAAC	Distributed Active Archive Centers
DAS	days-at-sea
DMSP	Defense Meteorological Satellite Program

DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
EA	Office of Education Affairs
EASC	Eastern Administrative Support Center
EC	European Community
ECDIS	Electronic Chart Display Information Systems
EEOC	Equal Employment Opportunity Commission
EEZ	Exclusive Economic Zone
ENSO	El Niño-Southern Oscillation
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
EPA	Environmental Protection Agency
EPOCS	Equatorial Pacific Ocean Climate Studies
ERL	Environmental Research Laboratories
ESA	Endangered Species Act
ESA	Economics and Statistics Administration
ESA	European Satellite Agency
ESDIM	Environmental Sciences Data Information Management
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization
FCCSET	Federal Coordinating Committee for Science, Engineering, and Technology
FDA	Food and Drug Administration
FMP	Fishery Management Plan
FNOC	Fleet Numerical Oceanography Center
FRAM	Fleet Replacement and Modernization
FSL	Forecast Systems Laboratory
FSM	Federated States of Micronesia
FSU	Florida State University
GCDIS	Global Change Data and Information System
GCIP	GEWEX Continental-Scale International Project
GCM	Global Circulation Model
GCOS	Global Climate Observing System
GDP	Gross Domestic Product
GEF	Global Environment Facility
GEOSAT	Geodetic Satellite
GEWEX	Global Energy and Water Cycle Experiment
GFDL	Geophysical Fluid Dynamics Laboratory
GFO	GEOSAT Follow-On
GIS	Geographic Information System
GLOBEC	Global Ocean Ecosystem Dynamics Studies
GMS	Geostationary Meteorological Satellite
GNP	Gross National Product
GOALS	Global Ocean-Atmosphere-Land System (Program)
GOES	Geostationary Operational Environmental Satellite
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GSA	General Services Administration
GSAT	Global Satellite Data Acquisition Team
GTS	Global Telecommunications System
HACCP	Hazard Analysis Critical Control Point
HAZMAT	Hazardous Materials Response and Assessment Division

HPCC	High Performance Computing and Communications
HVAC	Heating, Ventilation, Air Conditioning
IAI	Inter-American Institute for Global Change Research
IATTC	Inter-America Tropical Tuna Commission
ICCAT	International Convention on Conservation of Atlantic Tuna
ICSU	International Council of Scientific Unions
IDN	International Directory Network
IGBP	International Geosphere-Biosphere Program
IITA	Information Infrastructure Technology Applications
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute
IT-95	Information Technology 1995
ITQs	Individual Transferable Quotas
IUCN	The World Conservation Union
IUSS	Integrated Undersea Surveillance System
IWC	International Whaling Commision
JAWF	Joint Agriculture-Weather Facility
JGOFS	Joint Global Ocean Flux Study
JIC	Joint Ice Center
LANL	Los Alamos National Laboratory
LAWS	Laser Atmospheric Wind Sounder
LBS	Land-based Sources of Marine Pollution
LIDAR	light detecting and ranging
LME	Large Marine Ecosystem
LMR	Living Marine Resource
MAFAC	Marine Fisheries Advisory Committee
MAPS	Mesoscale Analysis and Prediction System
MDB	Multilateral Development Bank
MEDS	Marine Ecological Database System
METCON	Metropolitan Consortium for Minorities in Science and Engineering
MFCMA	Magnuson Fishery Conservation and Management Act
MMPA	Marine Mammal Protection Act
MOM	Modular Ocean Model
MPP	massively parallel processor
MTPE	Mission To Planet Earth
NAD83	North American Datum of 1983
NAS	National Academy of Sciences
NAS	Nonindigenous Aquatic Species
NASA	National Aeronautics and Space Administration
NASC	North Atlantic Salmon Convention
NAVD88	North American Vertical Datum of 1988
NAVO	Naval Oceanographic Office
NAWAS	National Warning System
NC	NOAA Corps
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NCM	National Coastal Monitoring
NCOPO	NOAA Coastal Ocean Program Office
ND	Office of the Naval Deputy
NEPA	National Environmental Policy Act

NERRS	National Estuarine Research Reserve System
NESDIS	National Environmental Satellite, Data, and Information Service
NEXRAD	Next Generation Weather Radar
NGDC	National Geophysical Data Center
NIC	Network Information Center
NII	National Information Infrastructure
NIST	National Institute for Standards and Technology
NMC	National Meteorological Center
NMFS	National Marine Fisheries Service
NMS	National Marine Sanctuary
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPL	National Priorities List
NRC	National Research Council
NREN	National Research and Education Network
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSP	Neurological Shellfish Poisoning
NSRS	National Spatial Reference System
NSTA	National Science Teachers Association
NSTC	National Science and Technology Council
NTIA	National Telecommunications and Information Administration
NTIS	National Technical Information Service
NURP	National Undersea Research Program
NWS	National Weather Service
NYT	New York Times
OA	Office of Administration
OAR	Office of Oceanic and Atmospheric Research
OCFS	Operational Climate Forecast Services
OCR	Office of Civil Rights
OCRM	Office of Coastal Resource Management
OCS	Office of the Chief Scientist
OEA	Office of External Affairs
OECD	Organization for Economic Cooperation and Development
OFCM	Office of the Federal Coordinator for Meteorology
OGP	Office of Global Programs
OMB	Office of Management and Budget
OOC	Operational Oceanography Center
ONCO	Office of NOAA Corps Operations
OPC	Ocean Products Center
OPM	Office of Personnel Management
OR&F	Operations, Research and Facilities
ORTA	Office of Research and Technology Applications
OSAA	Operational Satellite Active Archive
OTH	Over-the-Horizon
PC	Personal Computer
PCO	Program Coordination Office
PIN	Pacific Island Network
POES	Polar Operational Environmental Satellite
PORTS	Physical Oceanographic Real-Time System
PSP	Paralytic Shellfish Poisoning
PSP	Office of Policy and Strategic Planning
PTO	Patent and Trademark Office
R&D	research and development

RCC	Regional Climate Center
RCRA	Resource Conservation and Recovery Act
RFC	River Forecast Center
RI/FS	Remedial Investigation/Feasibility Study
RMI	Republic of the Marshall Islands
RSMC	Regional Specialized Meteorological Center
RSMIS	A real property or computerized data base
RSSA	Resource Services Support Agreement
RTE	repairs-to-extend
SAA	Satellite Active Archive
SAIC	Science Applications International Corporation
SAR	Synthetic Aperture Radar
SBIR	Small Business Innovation Research
SCPP	Seasonal to Interannual Climate Prediction Program
SD	Office of Sustainable Development and Intergovernmental Affairs
SeaWiFS	Sea-Viewing, Wide Field-of-view Sensor
SEPESCA	Mexican Secretariat of Fisheries
SES	Senior Executive Service
SESC	Space Environment Services Center
SIO	Scripps Institution of Oceanography
SOSUS	Sound Surveillance System
SPN	Shared Processing Network
SPO	Systems Program Office
SPREP	South Pacific Regional Environment Program
SSMC	Silver Spring Metro Complex
SST	Sea Surface Temperature
SURTASS	SURveillance Towed Array Sensor System
SUSCOS	Subcommittee on U.S. Coastal Ocean Science
SWATH	Small Waterplane Area Twin Hull
TAO	Tropical Atmosphere Ocean
TED	Turtle Excluder Device
TEMA	Training, Education, and Mutual Assistance
TOGA	Tropical Ocean Global Atmosphere (Program)
TOPEX	Ocean Topography Experiment
TOS	TOGA Observing System
TRMM	Tropical Rainfall Measuring Mission
U.S.	United States
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNOLS	University-National Oceanographic Laboratory System
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geologic Survey
USIS	U.S. Information Service
UV-B	Ultraviolet-Biological
VCP	Voluntary Cooperation Program
VHPCC	Very High Performance Computing and Communications
VOS	Voluntary Observing Ship
WAM	wave model
WCRP	World Climate Research Programme

WDC	World Data Center
WFO	Weather Forecast Office
WGD	Working Group on Data
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WSFO	Weather Service Forecast Office
WSR-88D	Weather Surveillance Radar
WWR	World Weather Records
WWW	World Weather Watch
XBT	Expendable Bathythermograph

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