EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES

STRATEGIC PLAN FOR THE U.S. INTEGRATED EARTH OBSERVATION SYSTEM

Interagency Working Group on Earth Observations
NSTC Committee on Environment and Natural Resources

The National Science and Technology Council

The National Science and Technology Council (NSTC), a cabinet level council, is the principal means for the President to coordinate science, and technology policies across the Federal Government. NSTC acts to coordinate the diverse parts of the Federal research and development enterprise.

An important objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in areas ranging from information technologies and health research to improving transportation systems and strengthening fundamental research. This council prepares research and development strategies that are coordinated across Federal agencies to form an investment package that is aimed at accomplishing multiple national goals.

To obtain additional information regarding the NSTC, contact the NSTC Executive Secretariat at (202) 456-6101

The Committee on Environment and Natural Resources

The Committee on Environment and Natural Resources (CENR) is one of four committees under the NSTC. It is charged with improving coordination among federal agencies involved in environmental and natural resources research and development, establishing a strong link between science and policy, and developing a federal environment and natural resources research and development strategy that responds to national and international issues.

To obtain additional information regarding the CENR, contact the CENR Executive Secretariat at (202) 482-5921.

The Interagency Working Group on Earth Observations

The Interagency Working Group on Earth Observations was chartered by the CENR for the purpose of developing the Strategic Plan for the U.S. Integrated Earth Observation System, and to provide U.S. contributions to the Global Earth Observation System of Systems (GEOSS). The Interagency Working Group's charter expired in December, 2004, and the working group has been replaced with a standing subcommittee under CENR, the United States Group on Earth Observations (US GEO).

To obtain additional information regarding the US GEO, contact the US GEO Executive Secretariat at (202) 482-5921.

EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

STRATEGIC PLAN FOR THE U.S. INTEGRATED EARTH OBSERVATION SYSTEM

Interagency Working Group on Earth Observations
NSTC Committee on Environment and Natural Resources

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL
WASHINGTON, D.C. 20502

April 6, 2005

Dear Colleague:

On February 16, 2005, 55 countries endorsed a 10-year plan to develop and implement the Global Earth Observation System of Systems (GEOSS) for the purpose of achieving comprehensive, coordinated, and sustained observations of the Earth system. GEOSS will allow scientists and policy makers in many different countries to design, implement and operate integrated Earth observing systems in a compatible, value-enhanced way. It will link existing satellites, buoys, weather stations, and other observing instruments that are already demonstrating value around the globe and support the development of new observational capabilities where required.

The U.S. contribution to GEOSS is the Integrated Earth Observation System (IEOS). IEOS will meet our country's need for high-quality, global, sustained information on the state of the Earth as a basis for policy and decision making in every sector of our society. In many areas, observations are already being collected. In others, observational gaps will be identified and assessed to determine if their value outweighs the investment required to fill them.

This strategic plan for IEOS is organized around nine initial societal benefit areas and six near-term opportunity areas. These provide a working framework for prioritizing actions and addressing critical gaps that maximize return on investments. The plan represents eighteen months of work by the seventeen federal agencies represented on the Interagency Working Group on Earth Observations (IWGEO), which has now been formally established as the Group on Earth Observation (US GEO), a standing Subcommittee reporting to the National Science and Technology Council's (NSTC) Committee on Environment and Natural Resources (CENR).

The breadth and scope of the plan is unprecedented, and much work remains to realize the full potential of our Nation's investment in Earth observations. The exemplary leadership of the US GEO will ensure continued excellence in the IEOS and maximize U.S. contributions to the GEOSS.

Sincerely,

John Marburger

John H. Marburger, III
Director

INTERAGENCY WORKING GROUP ON EARTH OBSERVATIONS
OF THE
NSTC COMMITTEE ON ENVIRONMENT AND NATURAL RESOURCES

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United States Agency for International Development

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EXECUTIVE SUMMARY

***A global system of Earth observations** would provide us with tools to make national and global air quality forecasts, would help us to know in advance when droughts would occur and how long they would last, and would give us the capability to predict the outbreak of deadly diseases by tracking the environmental factors that contribute to their spread. The availability of these types of observational data would transform the way we relate and react to our environment, providing significant societal benefits through improved human health and well-being, environmental management, and economic growth.*

Vision Statement

Enable a healthy public, economy, and planet through an integrated, comprehensive, and sustained Earth observation system.

These and other societal benefits depend on a sustained and integrated Earth observation system underpinned by science and technology. Investments by the United States and our foreign partners over the last decade have provided unprecedented global views of the Earth as a set of complex, interacting processes. Despite these advances, our current system of observations is fragmented and incomplete. Now, using a new integrated approach, we must improve our Earth observation system so that we realize benefits for our people, our economy and our planet.

The National Science and Technology Council's Interagency Working Group on Earth Observations has prepared this Strategic Plan as the first step in the planning process towards the development and implementation of the *U.S. Integrated Earth Observation System (IEOS).* In the context of broad, crosscutting societal, scientific, and economic imperatives, and the missions and priorities of the agencies participating in the Interagency Working Group on Earth Observations, the approach for the development of the U.S. Integrated Earth Observation System is to focus on specific and achievable societal benefits. The task is to integrate the nation's Earth observation capabilities to address those imperatives and realize societal benefits. The planning process will identify and integrate new capabilities on the horizon. In addition, technology and capability gaps must be identified and addressed before societal benefits can be fully realized. By developing the infrastructure to facilitate the integration and synthesis of data and information products and services across multiple domains, new value-added information/knowledge solutions can be realized. New information products, new tools, and new web-based services will be developed to address current and future applications.

1. **Improve Weather Forecasting**
2. **Reduce Loss of Life and Property from Disasters**
3. **Protect and Monitor Our Ocean Resource**
4. **Understand, Assess, Predict, Mitigate, and Adapt to Climate Variability and Change**
5. **Support Sustainable Agriculture and Forestry, and Combat Land Degradation**
6. **Understand the Effect of Environmental Factors on Human Health and Well-Being**
7. **Develop the Capacity to Make Ecological Forecasts**
8. **Protect and Monitor Water Resources**
9. **Monitor and Manage Energy Resources**

Nine societal benefit areas (see green box) provide a starting place for discussion about what can be accomplished in several key areas where work is underway, and where progress can be realized most quickly. In this Strategic Plan, specific examples illustrate the link between observations and identified benefits.

For decades, U.S. Federal agencies have been working with industry, academia, local, state, national, regional and international partners to strengthen cooperation in Earth observations. U.S. Federal agencies have developed and funded a broad range of training and outreach activities to provide the expertise in science, mathematics, and engineering needed to develop an integrated Earth observation system. These information and K-12 programs that provide useful information to our students and promote awareness and understanding of the benefits of an integrated system are important components of these efforts. The United States will continue to work with the nations of the world to develop and link observation technologies for tracking environmental changes in every part of the globe, thus enabling citizens and leaders to make more informed decisions affecting their lives, environment, and economies.

The Earth is an integrated system. All the processes that influence conditions on the Earth, whether ecological, biological, climatological, or geological, are linked, and impact one another. Therefore, Earth observation systems are strengthened when data collection and analysis are achieved in an integrated manner. This Strategic Plan discusses the process for determining which observations should be integrated and outlines four areas of integration: Policy and Planning Integration, Specific and Issue Focused Integration, Scientific Integration and Technical Integration.

This plan recommends the establishment of a standing Earth observation subcommittee under the auspices of the National Science and Technology Council's Committee on Environment and Natural Resources. This Subcommittee will oversee the implementation of the principles and guidelines described here. The Subcommittee will be charged with coordinating vastly expansive science and technical activities to satisfy the identified societal benefits.

This Strategic Plan addresses the policy, technical, fiscal, and societal benefit components of an integrated Earth observation system.

- The policy component identifies the aspects of Earth observations that will be defined as mandates or guidelines at the Federal level. Additionally, this policy component addresses data sharing and the identification of critical observations, and recognizes the requirement for decisions based on sound science and defined need.
- The technical component describes the architectural approach, noting that this system will build upon existing systems. This component of the plan will also identify and document observation gaps and needs in the societal benefits areas, and, where possible, note promising new capabilities and technology developments that could address them.
- The fiscal component points out the need for a process for identification of agency budgetary priorities within the framework of the Office of Management and Budget's research and development investment criteria, leading to overall prioritization of Earth observation activities.
- The societal benefit approach provides a framework for discussing improvements in multiple key areas. This component identifies broad societal, scientific, and economic imperatives that transcend the specific needs and mandates of individual participating agencies.

- Observation for scientific purposes overlaps with and is deeply involved in Earth observation for scientific benefit. Scientific priorities for Earth Observation are developed by agencies with the help of the scientific community through such means as National Research Council reports.

The functions of the U.S. Integrated Earth Observation System include data collection, data management, data discovery, data access, data transport, data archiving, processing, modeling, and quality control. Because no comprehensive and integrated strategy for communicating all the current data exists, *enhanced data management* is highlighted as both an overarching need and a critical first near-term action. In addition, using tangible, achievable examples, the Strategic Plan points out some near-term opportunities of the U.S. Integrated Earth Observation System, and illustrates the observational needs and societal benefits associated with improved observations for disaster warning, global land cover, sea level, drought, and air quality.

Finally, the plan identifies next steps, recognizing the need for establishing an organizational structure and describing the near-, mid- and long-term actions that are needed to develop the common system architecture required for the success of the U.S. Integrated Earth Observation System.

The U.S. Integrated Earth Observation System will provide the nation and the world a unique and innovative perspective on the complex, interacting processes that make up our planet. This observation system should continue to evolve to meet the changing needs of society and to take into account emerging technologies and scientific advances. Implementing the U.S. Integrated Earth Observation System represents an exciting opportunity to make lasting improvements in U.S. capacity to deliver specific benefits to our people, our economy and our planet.

INTRODUCTION

***A global system of Earth observations** would provide us with tools to make national and global air quality forecasts in the same way we currently make weather forecasts. Think of the benefits to the millions of Americans suffering from asthma.*

***A global system of Earth observations** would help us know in advance when droughts would occur and how long they would last. Think of the benefits to the millions of farmers who could plan their planting and harvesting with increased confidence.*

***A global system of Earth observations** would give us the capability to predict the outbreak of deadly diseases by tracking the environmental factors that contribute to their spread. Think of the benefits to world health and economies.*

Realization of these and other benefits is dependent upon a sustained, integrated, and constantly evolving Earth observation system underpinned by science and technology. Today we have sophisticated tools to increase the efficiency and effectiveness of Earth observations, unparalleled opportunities for collecting and synthesizing the vast amount of data they provide, and the

World Summit on Sustainable Development
August 2002

G-8 Action Plan on Science and Technology for Sustainable Development
June 2003

Earth Observation Summit I
July 2003

Group on Earth Observations
Established August 2003

Interagency Working Group on Earth Observations
Established August 2003

Earth Observation Summit II
April 2004

G-8 Science Ministers Meeting
April 2004

G-8 Science & Technology Action Plan/Progress Report
June 2004

Earth Observation Summit III
February 2005

Box 1: Recent international emphasis on Earth observations

expanded capability to deliver this data to end users for practical applications.

Over the past decade, the investments made by the United States and our international partners have provided unprecedented global views of the Earth as a set of complex, interacting systems. Despite significant advances in our ability to measure and understand the Earth, building a comprehensive, integrated, and sustained Earth observation system remains a major challenge. Future investments must not only improve tools and capabilities, but must focus on an integrated approach, serving a diverse set of users and ultimately realizing a wide range of benefits for our people, our economy, and our planet.

Recent progress in coordinated international planning (box 1), building upon decades of scientific and technical successes, provides a unique opportunity to plan and implement an integrated, comprehensive and sustained Earth observation system.

Building on this progress, the Interagency Working Group on Earth Observations has prepared this Strategic Plan as the first step towards the development and implementation of the *U.S. Integrated Earth Observation System.* This Strategic Plan provides a pathway towards the development of the integrated system. The scientific and technical foundations for the vision and implementation approach have been developed over the past year by the agencies of the Interagency Working Group on Earth Observations (box 2) (terms of reference in Appendix 1).

This document responds to the guidance in the 2003 White House Office of Science and Technology Policy/Office of Management and Budget FY2005 Interagency Research and Development Priorities memorandum, which charged the National Science and Technology Council to enhance capabilities to assess and predict changes in key environmental systems.

Interagency Working Group on Earth Observations Membership

Department of Commerce
- National Oceanic and Atmospheric Administration
- National Institute for Standards and Technology

Department of Defense
- Air Force
- National Geospatial-Intelligence Agency
- Navy
- U.S. Army Corps of Engineers

Department of Energy

Department of Health & Human Services
- National Institute of Environmental Health Sciences

Department of Homeland Security
- Federal Emergency Management Agency

Department of the Interior
- US Geological Survey

Department of State

Department of Transportation

Environmental Protection Agency

National Aeronautics and Space Administration

National Science Foundation

Smithsonian Institution

Tennessee Valley Authority

U.S. Agency for International Development

U.S. Department of Agriculture
- Agriculture Research Service
- U.S. Forest Service

White House Council on Environmental Quality

White House Office of Management and Budget

White House Office of Science and Technology Policy

Box 2: Interagency Working Group on Earth Observations

The National Science and Technology Council, through its Committee on Environment and Natural Resources, established the Interagency Working Group on Earth Observations to develop and implement a coordinated, multi-year plan for Earth observations. This Strategic Plan builds on existing and evolving scientific and technical plans and is intended to improve our understanding, monitoring and prediction of changes to the Earth system (including atmosphere, land, fresh water, ocean, and ecosystems). We will continue to refine the Plan as technology develops and as we achieve its goals.

To continue and sustain the efforts of the Interagency Working Group on Earth Observations, this plan calls for the establishment of a standing Earth observation subcommittee (in the National Science and Technology Council and under the Committee on Environment and Natural Resources) with responsibility to implement the principles and guidelines developed here. The Subcommittee will continue to pull together vastly expansive science and technical activities to satisfy the diverse societal benefits, leading towards an integrated, comprehensive and sustained Earth observation system—the U.S. Integrated Earth Observation System.

PURPOSE, VISION AND GOALS

A. Purpose

For decades, U.S. Federal agencies have been working with local, state, national, regional and international partners to strengthen cooperation in Earth observations. Building on this work, the U.S. Interagency Working Group on Earth Observations prepared this Strategic Plan to provide a management, planning, and resource allocation strategy for a U.S. Integrated Earth Observation System. This strategy will provide the United States a framework for participating in the international effort to develop a 10-year plan for a Global Earth Observation System of Systems. This U.S. integrated system will be based on new and existing Earth observation systems and capabilities, and will be developed to meet national and international societal, scientific, and economic imperatives.

Vision Statement

Enable a healthy public, economy, and planet through an integrated, comprehensive, and sustained Earth observation system.

B. Vision

A comprehensive Earth observation system will benefit people around the world by improving our ability to monitor, understand, and predict changes to the Earth. The United States will work with other nations to develop and link observation technologies for tracking environmental changes in every part of the globe, thus enabling citizens and leaders to make more informed decisions affecting their lives, environment, and economies. This international cooperation, along with new developments in monitoring, assessing, and predicting environmental changes, will enable development of capabilities to predict droughts, prepare for weather emergencies and other natural hazards, plan and protect crops, manage coastal areas and fisheries, and monitor air quality, to name but a few direct benefits that affect our economic prosperity and quality of life.

C. Goals for U.S. Integrated Earth Observation System

To accomplish the purpose and vision of the U.S. Integrated Earth Observation System, the agencies will:

- Identify current and evolving requirements in the full range of societal benefits.
- Prioritize investments, including for new requirements, as necessary.
- Utilize available and/or develop new technologies, instruments, systems, and capabilities to meet the identified requirements and priorities.
- Streamline and sustain existing Earth observation systems that are necessary to achieve societal benefits.

- Establish U.S. policies for Earth observations and data management, and continue U.S. policies of open access to observations, encouraging other countries to do likewise.
- Expand existing governmental partnerships at local, state, regional, tribal and Federal levels, and develop new long-term partnerships with industry, academia, the K-12 education community, non-governmental, and international organizations that further the realization of these strategic goals.
- Develop human and institutional capacity to enable the translation of observations into societal benefits.


EARTH OBSERVATION SUMMIT
GERMANY
GABON
FRANCE
EUROPEAN COMMISSION
EGYPT

LINKS TO INTERNATIONAL ACTIVITIES

International cooperation in Earth observations has already resulted in benefits greater than could be achieved by individual nations acting alone. The international scientific community, working together within key international organizations (such as the World Meteorological Organization and the Intergovernmental Oceanographic Commission), has improved understanding of environmental phenomena. Environmental observations and science are international in scope and in the very nature of their activity. International cooperation is a prerequisite for their success. Recognizing this, ministers from 34 nations and representatives from 25 international organizations met at the first Earth Observation Summit in July 2003. This meeting resulted in an international effort to develop a Global Earth Observation System of Systems.

This international effort emphasizes the importance of capacity building, as information from Earth observations is critical for developing as well as developed nations. Building capacity is integral to a global implementation strategy, which includes ensuring full utilization of the data. Growing world populations with expanding economies will require access to Earth observations for a wide range of societal, scientific, and economic needs. The development of new systems will contribute to the gross domestic product of countries. International contributions are also essential for completing the data sets needed to address important U.S. national issues.

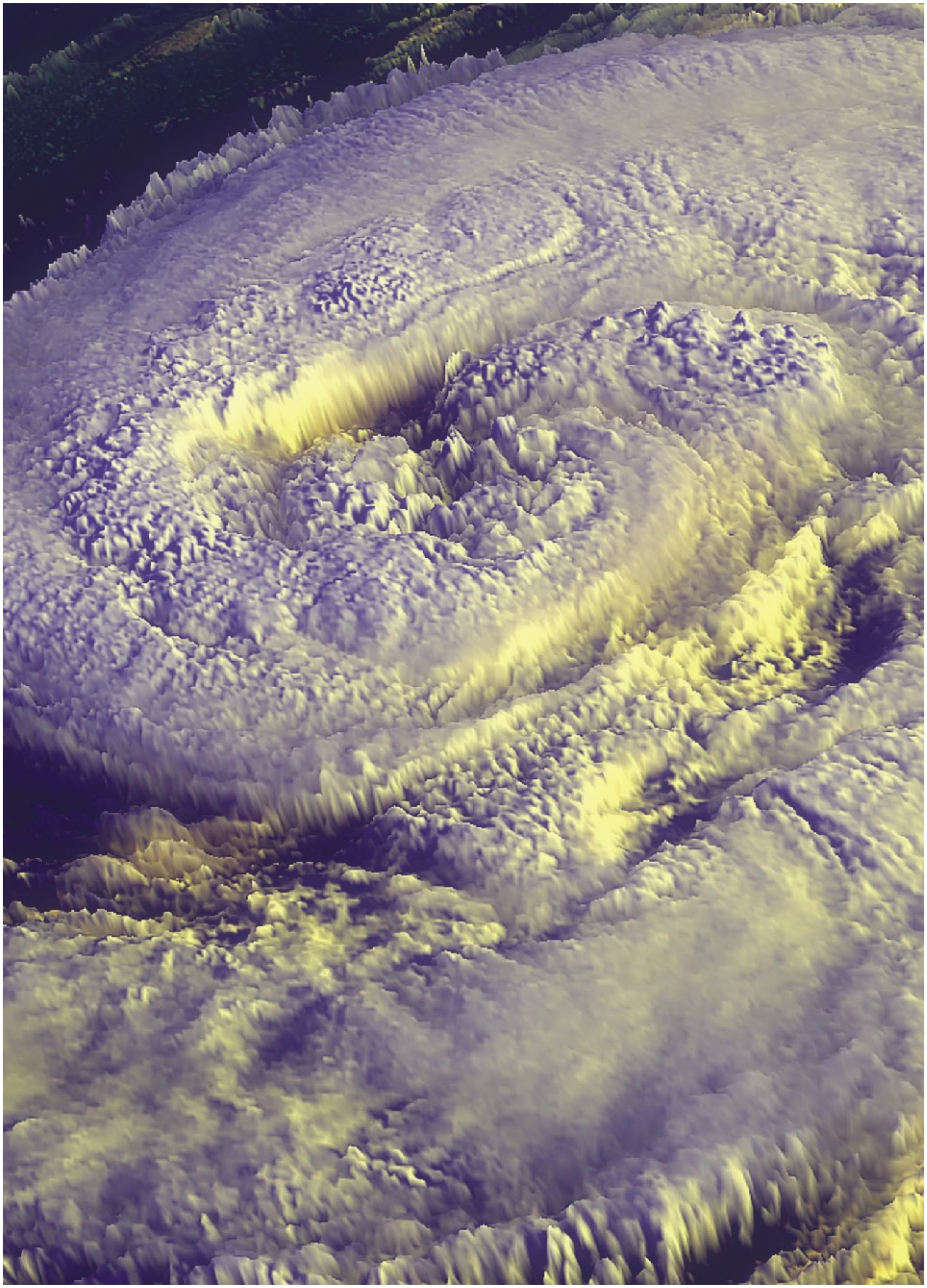
The development of this Strategic Plan addresses the first goal of the Interagency Working Group on Earth Observations and serves as the initial step towards the development and implementation of the *U.S. Integrated Earth Observation System.* A parallel ongoing goal of the interagency group is to formulate the U.S. position and input to the intergovernmental Group on Earth Observations (GEO) and the development of the Global Earth Observation System of Systems (GEOSS).

The U.S. Integrated Earth Observation System will also promote international capacity building, and the development of the U.S. Plan is a key element in formulating the U.S. contributions to the GEOSS.

An example of international cooperation on observations can be found in the ongoing development of a global system to monitor our oceans. For over a decade, concerted national and international efforts have taken place during the development of the Global Ocean Observing System (GOOS), which is being conducted under the auspices of UNESCO's International Oceanographic Commission, the World Meteorological Organization, the United Nations Environment Programme, and the International Council for Science. The Integrated Ocean/Coastal Observing System (IOOS) is the primary U.S. component of GOOS.

The International Polar Year (IPY) 2007-2008 is an additional example of an ongoing initiative being planned that will complement the global Earth observation effort. This international multidisciplinary campaign of polar observations, research, and analysis follows in the tradition of three international science endeavors during the last 125 years (IPY 1882-1883; IPY 1932-1933; IGY 1957-1958), when nations around the world united to advance scientific discovery in ways that single countries or scientists could not do alone.

IPY is a rapidly growing suite of collaborative activities focused on evaluating the status and current rate of change of both natural and human systems of the polar regions, and understanding the causes of those changes.



A PRACTICAL FOCUS FOR EARTH OBSERVATIONS

Our approach for developing the U.S. Integrated Earth Observation System is to focus on specific and achievable societal benefits and to link U.S. efforts to international activities.

Based on discussions about the needs and priorities of the agencies participating in the Interagency Working Group on Earth Observations, nine societal benefit areas (box 3) were chosen as the preliminary focus. This list was then vetted and approved by the National Science and Technology Council Committee on Environment and Natural Resources. This list is not in order of priority, nor is it meant to be exhaustive or static. It is intended to provide a framework for discussion about improvements in several key areas where work is underway. These benefit areas are described further in the next section of this document (and detailed in Appendix 2).

1. **Improve Weather Forecasting**
2. **Reduce Loss of Life and Property from Disasters**
3. **Protect and Monitor Our Ocean Resource**
4. **Understand, Assess, Predict, Mitigate, and Adapt to Climate Variability and Change**
5. **Support Sustainable Agriculture and Forestry, and Combat Land Degradation**
6. **Understand the Effect of Environmental Factors on Human Health and Well-Being**
7. **Develop the Capacity to Make Ecological Forecasts**
8. **Protect and Monitor Water Resources**
9. **Monitor and Manage Energy Resources**

Box 3: Preliminary set of societal benefit areas

In the past, individual government agencies sought to implement and optimize their observation systems to meet their specific needs and mandates. The U.S. Integrated Earth Observation System transcends individual agency perspectives and focuses the activity on broad societal, scientific, and economic imperatives.

A. A Healthy Public—Societal Imperatives

A growing world population, projected to increase by roughly 50% in the next 50 years before leveling off,[1] will place increasing demands on crucial resources like food and clean water and air. Populations and economic activities are shifting from rural areas to urban centers, many in low-lying coastal regions or seismically active zones. In the United States, more than half of the population lives within 50 miles of our coasts,[2] areas that are particularly vulnerable to storm surges and flooding. We rely upon coastal regions for healthy fisheries, and reliable transport and navigation. Increased dependence on infrastructure networks (roads, power grids, oil and gas pipelines) intensifies the potential vulnerability of more developed societies to impacts from natural disasters.

Another potential health-related benefit from improved observations concerns the quality of our air. Despite dramatic improvements in air quality in the United States over the last 30 years, over 100 million people in the U.S. still live in counties with pollution levels that exceed National Ambient Air Quality Standards (NAAQS), posing potential health problems.[3] Improved understanding of the complex workings of Earth systems will help us protect society and manage our resources and infrastructure in a more efficient and effective way.

B. A Healthy Economy—Economic Imperatives

In pure economic terms, studies show that national institutions that provide weather, climate, public health, and water services to their citizens contribute an estimated $20-$40 billion dollars each year to their national economies.[4] In the United States, weather- and climate-sensitive industries, both directly and indirectly, account for as much as 1/3 of our nation's GDP—$2.7 trillion[5]—ranging from agriculture, energy, finance, insurance, transportation, and real estate, to retail and wholesale trade, and manufacturing. Economists have quantified the benefits of improved El Niño forecasts to be an estimated $265-300 million annually, throughout El Niño, normal and La Niña years. Likewise, annual benefits in a small Northwest Coho salmon fishery are estimated at $250,000 to $1 million.[6] The return on our investments for Earth observations has brought great benefits to the general public. However, we can do much more.

C. A Healthy Planet—Scientific Imperatives

Improved management of resources and forecasting of Earth system changes cannot be achieved without a much more comprehensive and detailed understanding of the Earth. We are faced with a number of pressing science questions, such as:

- How are all of Earth's "life support systems" interrelated?
- How do geophysical phenomena and biogeochemical phenomena relate?
- How do social and economic factors interrelate with Earth system changes?

These questions call for an interdisciplinary Earth science approach to provide useful answers. We need to know how the parts fit together and function as a whole.

The multiple components and processes of the Earth's atmosphere, ocean and land surfaces operate interactively, as a complex, dynamic system. More importantly, the multiple "feedback loops" operating among component processes of the hydrosphere, geosphere, atmosphere, and biosphere determine the state of the Earth system at any given time. In order to take the "pulse of the planet," we must establish a valid end-to-end process that will take us from observations to user-related products. Scientific needs for this end-to-end process require that we:

- integrate observation, data management, and information delivery systems,
- quantify environmental processes by direct or indirect observations,
- improve coupled Earth system models that integrate the best state of knowledge,
- assimilate the Earth observation data streams into models (eventually in real time),
- test our Earth system models over varying time and spatial scales against observations and the geologic/environmental record,
- understand the drivers of climate variability and change, the rates of change and the possible precursors to climate variability and change,
- understand and explain the forces, processes, mechanisms, and feedbacks underlying observed patterns, and
- communicate that scientific understanding to all stakeholders.

Scientific research and observation lead to the Earth System Models, which are the starting point of the observations-to-societal benefits paradigm developed in the next section.

LINKING OBSERVATIONS TO SOCIETAL BENEFITS

Connections between societal benefits and Earth observations must be clear to both decisions makers and the general public. In the following sections, we illustrate the expected linkage between observations and societal benefits in nine specific areas.[7] In selected cases, we illustrate how this linkage is achieved today.

Figure 1 depicts the linkage and flow of information from observations to societal benefits. Although the focus is on achievable specifics, the approach

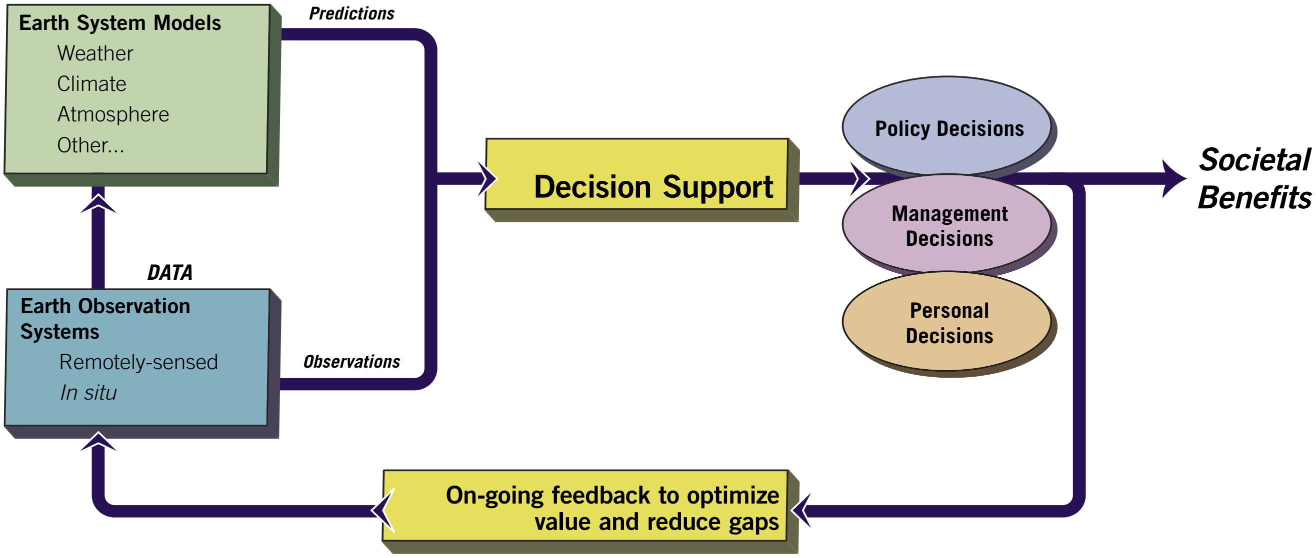


Figure 1: Linking Earth Observations to Societal Benefits

includes using a common system architecture, and ensuring current and evolving systems are interoperable and the solutions can be easily expanded, extended, and/or replicated to address future challenges.

A. Improve Weather Forecasting[8]

Weather is an important area and vital to the other societal benefits. Weather observation, along with the associated national and international data management mechanisms, is probably the most mature observation system example in wide use today. The current weather system provides billions of dollars in value to the nation in areas such as transportation safety, agricultural productivity, and energy management. Enhanced observations would greatly facilitate the weather mission in the U.S., as well as supply crosscutting information for the user requirements in the other societal benefit areas. For example, high-resolution lower-atmosphere global wind measurements from a spaceborne optical sensor would dramatically improve a critical input for global prediction models, improving long-term weather forecasting.

B. Reduce Loss of Life and Property from Disasters[9]

Natural hazards such as earthquakes, volcanoes, landslides, floods, wildfires, extreme weather, coastal hazards, sea ice and space weather, plus major pollution events, impose a large burden on society. In the US, the economic cost of disasters averages $20 billion dollars per year.[10] Disasters are a major cause of loss of life and property. The recent California wildfires and the Denali Alaska earthquake underline the importance of preparedness, planning, and response. Our ability to predict, monitor, and respond to natural and technological hazards is a key consideration in reducing the impact of disasters.

Sensors onboard geostationary satellites known as GOES supply observations used to detect and monitor forest fires every half-hour for the entire Western Hemisphere, including remote areas. This allows early detection of fires and indicates whether or not they are intensifying. During the 2001 Viejas fire in San Diego, the GOES observation product recognized the fire 15 minutes after the estimated ignition time. This product is available within minutes (http://cimss.ssec.wisc.edu/goes/burn/wfabba.html). To extend the fire monitoring coverage beyond the Western Hemisphere, data from the Terra and Aqua research satellites and other international polar orbiting satellites, are combined with GOES data to create a global fire map. Polar orbiting satellite data are currently used to create active fire maps for the U.S. (http://activefiremaps.fs.fed.us/). Fire incident maps, generated daily for use by firefighters on the ground, require higher-resolution (usually airborne) infrared imagery, superimposed on topography of the area.

C. Protect and Monitor Our Ocean Resource[11]

Ocean resources account for a significant portion of the U.S. economy, and recent estimates indicate that coastal areas provide 28 million jobs, millions of dollars in goods and services, and tourist destinations for over 180 million Americans per year. Our ability to observe and manage coastal and marine resources will continue to provide these key benefits to society. Managing ocean resources requires accurate information from an integrated observation system to allow for detection and prediction of the causes and consequences of changes in marine and coastal ecosystems, watersheds and non-living resources.

The recommendations of the U.S. Commission on Ocean Policy (2004) (see http://www.oceancommission.gov/documents/prepub_report/welcome.html), the U.S. Ocean Action Plan (see http://ocean.ceq.gov/), White Water to Blue Water (see http://www.state.gov/g/oes/rls/fs/2002/15624.htm) and other reports and studies endorse an ecosystem approach and/or a watershed approach for observation systems. These systems should be able to assess and predict phenomena such as impacts of events like coastal storms, oil spills, pollution, and other activities such as fishing, recreational activities, marine transportation, coastal activities and ocean drilling/exploration. Observations are needed for a wide range of physical, biological, chemical, geological and atmospheric variables within U.S. coastal regions, islands and territories, and open ocean regions. Coordination of this information obtained at various time and space scales, and from existing and planned networks, along with indicators, models and decision support systems can provide great benefits to society.

D. Understand, Assess, Predict, Mitigate, and Adapt to Climate Variability and Change[12]

The Earth's climate is a dynamic system undergoing continuous change on seasonal, annual, decadal and longer timescales. Scientific evidence suggests that a complex interplay of natural and human-related forces may explain such climate variability and change. Better preparation for any impacts due to climate variability and change requires better understanding of its causes and effects. According to the National Academy of Sciences, improved global observation is a fundamental need for filling knowledge gaps in climate science. Noting that climate models are based on observations and that "the observation system available today is a composite of observations that neither provides the information nor the continuity in data needed to support measurements of climate variables," the Academy called for creation of a long-term observation system able to fill such existing data gaps.[13] In addition, a better understanding of greenhouse gas accounting and carbon management would greatly facilitate decision-making related to sustainable development of terrestrial, oceanic and atmospheric resources.

The climate observation system, including the associated data management system, and the community of users constitute a climate *information* system. Climate data users include government agencies (Federal, state, local), private industries (electric utilities and gas industries, tourism, shipping, agriculture, fishing, insurance/reinsurance, etc.), universities, recreational organizations, and non-governmental organizations. Usage is diverse, including research and operational applications, policy making and coordinated planning for climate change adaptation and mitigation, as well as decision-making by businesses, organizations, and individuals. Coordination of acquisition of information, and support for its application, is a required ongoing activity of Federal agencies that participate in the Climate Change Science Program and the Climate Change Technology Program, under the Committee on Environment and Natural Resources of the National Science and Technology Council.

E. Support Sustainable Agriculture and Forestry, and Combat Land Degradation[14]

Food production is a national priority and it is characterized by fluctuations related to climate conditions, land management practices, agricultural technologies, market forces and investment. Seasonal and longer-term trends of temperature and rainfall patterns are a great influence on agricultural, desert and range, and forestry sectors. Success depends on farmers, ranchers, and foresters adapting to seasonal or longer-term changes, based on receiving timely and accurate information for decisions. Drought and extreme weather decrease food production, foster desertification, and harm forests. Improved observations, models, and predictions of critical parameters (such as weather, salinity, erosion and soil loss, fires, pests and invasive species) can help mitigate these effects on farms, ranges, and forests. The industry that provides food to America is global in nature, so having global knowledge of the environmental conditions that affect worldwide food supply is important to all Americans.

F. Understand the Effect of Environmental Factors on Human Health and Well-Being[15]

All the components of this integrated Earth observation system contribute to improving human health and well-being. Researchers, service providers, policy makers, and the public currently use Earth observations to understand environmental factors in order to make decisions and take actions. These decisions and actions help reduce the impact of disasters, protect and manage natural resources, adapt to and mitigate climate variation, support sustainable agriculture, forecast weather, protect areas valued for recreational, religious, or aesthetic purposes, and help prevent disease/dysfunction influenced by environmental exposures. In the near future, the Earth observations will feed into real-time measurements of environmental factors and will further enhance the ability to predict changes in these important indicators.

The ability to predict disease emergence and intensity has long been a dream of public health workers, economic planners and ordinary citizens. For those diseases that are influenced by environmental factors, the development of predictive models will open the door to the possibility that if one could link risk of disease with certain variables, one could eventually apply these models to predict occurrence and possibly control or prevent these diseases in human populations.

Enhanced Earth observations that lead to better air quality data and the ability to predict air pollution episodes would contribute to improvements in human health via: reduced incidence of acute attacks and deaths from chronic respiratory diseases such as asthma; fewer air pollution-related emergency room visits; and fewer days absent from school or work. Air pollution affects the environment in many ways that ultimately impact on our health and well-being: by reducing visibility; damaging crops, forests, and buildings; acidifying lakes and streams; and stimulating the growth of algae in estuaries. Rapid development and urbanization around the globe has created air pollution that threatens people everywhere, as air pollution can travel great distances across oceans and national boundaries.

G. Develop the Capacity to Make Ecological Forecasts[16]

The primary goal of ecological forecasting is to predict the effects of biological, chemical, physical, and human induced pressures on ecosystems and their components at a range of scales and over time, given a certain set of assumptions. Examples of such pressures include extreme natural events, climate variability and change, land and resource use, pollution, invasive species, and human/wildlife diseases. Earth observations and relevant modeling tools help identify key cause-effect relationships. Once certain cause-effect relationships are established, the goal then is to use Earth observation information to develop management strategies and options to reverse declining trends, reduce risks, and protect important ecological resources and associated processes. Such an approach provides critical support to long-term economic growth and sustainable development. The use of ecological indicators and forecasting will move us toward sustainable management of goods and services.

Ecological forecasting requires the acquisition of a wide range of environmental data, as well as development of models. As an example, Lifemapper (www.lifemapper.org) is an Internet and leading-edge information technology model that retrieves plant and animal records from the world's natural history museums. Lifemapper analyzes the data, computes the ecological profile of each species, maps where the species has been found and predicts where each species could potentially live. Lifemapper has been used to model and simulate the spread of emerging diseases, plant and animal pests, or invasive species of plants and animals and their effects on natural resources, agricultural crops and human populations. Environmental scientists have modeled and predicted the effects of local, regional and global climate change on Earth's species of plants and animals. Land planners and policy-makers have used Lifemapper to identify the highest priority areas for biodiversity conservation.

H. Protect and Monitor Water Resources[17]

The availability and quality of freshwater for humans are critical factors influencing the health and livelihood of people across the nation. Over one billion people in the world are currently without safe drinking water. Continued growth in human populations and water use, continued degradation of water supplies by contamination, and greater recognition of the needs for freshwater in order to support critical ecosystem functions could contribute to increasing scarcity and conflict over water supplies. By providing more complete and detailed water information and forecasts, decision-makers and the public could make better decisions on water supplies and activities that affect humans, plants, animals, and ecosystems.

The Great Lakes hold one-fifth of the Earth's freshwater and are one of the Nation's most important aquatic resources from an economic, geographic, international, ecological, and societal perspective. The Great Lakes continually face extremes in natural phenomena such as storms, erosion, high waves, high and low water levels, and climate variability, all of which influence water quality and efforts to restore habitat. Population growth in the region will continue to increase stressors on the Great Lakes, adding to the complexity of management issues. Enhanced and increased observations and systems coupled with indicators, models and decision support tools such as the Great Lakes Observation System (http://www.glc.org/glos/pdf/glosbrochure-web.pdf) will foster restoration activities including wetlands banking, rehabilitation of Brownfields sites, restoration of coastal wetlands and other habitats, establishment of protected areas, use of dredged material to enhance fish and wildlife habitat, improvement of water quality, fisheries management, and prevention and control of invasive species.

I. Monitor and Manage Energy Resources[18]

Energy management and monitoring are compelling needs throughout the world. Energy availability, use, and cost vary regionally. Focused efforts with improved Earth observations can help to optimize decision-making, and help provide needed energy supply, while protecting the environment and human health. For example, it has been estimated that improving weather forecast accuracy is critical for timely, safe, and cost effective transport of energy resources, as described in the newspaper excerpt below.[19]

> “The annual cost of electricity could decrease by at least $1 billion if the accuracy of weather forecasts improved 1 degree Fahrenheit… [The Tennessee Valley Authority] generates 4.8% of the USA’s electricity. Forecasts over its 80,000 square miles have been wrong by an average of 2.35 degrees the last 2 years, fairly typical of forecasts nationwide. Improving that to within 1.35 degrees would save TVA as much as $100,000 a day, perhaps more. Why? On Monday at 5:30 a.m., TVA’s forecast for today called for an average four-city high of 93 degrees in Memphis, Nashville, Knoxville and Chattanooga, rising from 71 degrees at 6

a.m. TVA has scheduled today's power generation based on this forecast and will bring on line a combination of hydro, nuclear, coal, wind, natural gas and oil plants as temperatures rise. It will buy wholesale electricity if that costs less than generating its own power. Gas plants are more expensive to operate than nuclear or coal, so TVA will fire up its 'peakers' only when it expects demand to be very high. If the average temperature comes in 1 degree hotter, rising to 94, TVA's customers will demand 450 more megawatts. There would be no time to fire up an idle gas plant, and the cost of last-minute wholesale electricity could skyrocket. 'There are times when electricity is $80 (per megawatt hour) a day ahead and $800 to $8,000 24 hours later,' says Robert Abboud of RGA Labs, which helps utilities with complex decisions. On the other hand, if the four-city temperature comes in a degree cooler than forecast, TVA may have fired up a plant unnecessarily, or bought electricity a day in advance that will go wasted. Temperature is most important, but utilities can also benefit from accurate forecasts of cloud cover and humidity..."

IMPLEMENTATION OF THE U.S. INTEGRATED EARTH OBSERVATION SYSTEM

The development of an integrated, comprehensive and sustained Earth observation system is a challenge that requires a structured plan for development. Figure 2 illustrates the U.S. approach to implementation, which begins with the clear definition of the *vision* (see page 5). After considering the missions and priorities of the participating agencies, the Interagency Working Group on Earth Observations identified nine *societal benefit* areas. Given the vision and the societal benefits that the system will address, the next steps include definition of the functional and performance *requirements* (box 4) necessary to guide the development of the integrated system *architecture.* The final step identifies the existing and planned *systems* to be *implemented* in the U.S. Integrated Earth Observation System architecture.

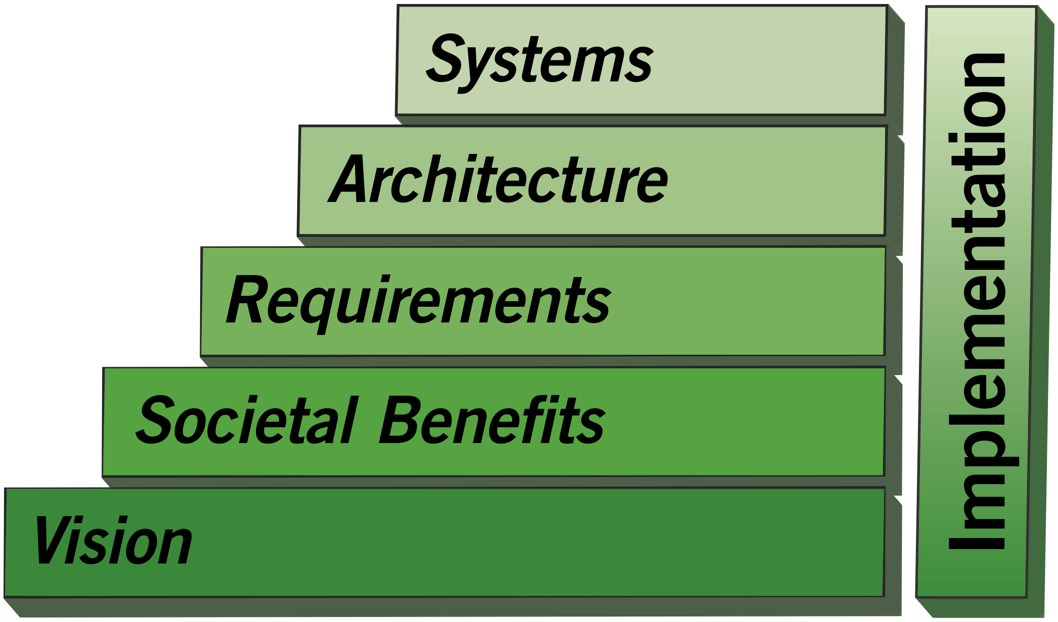


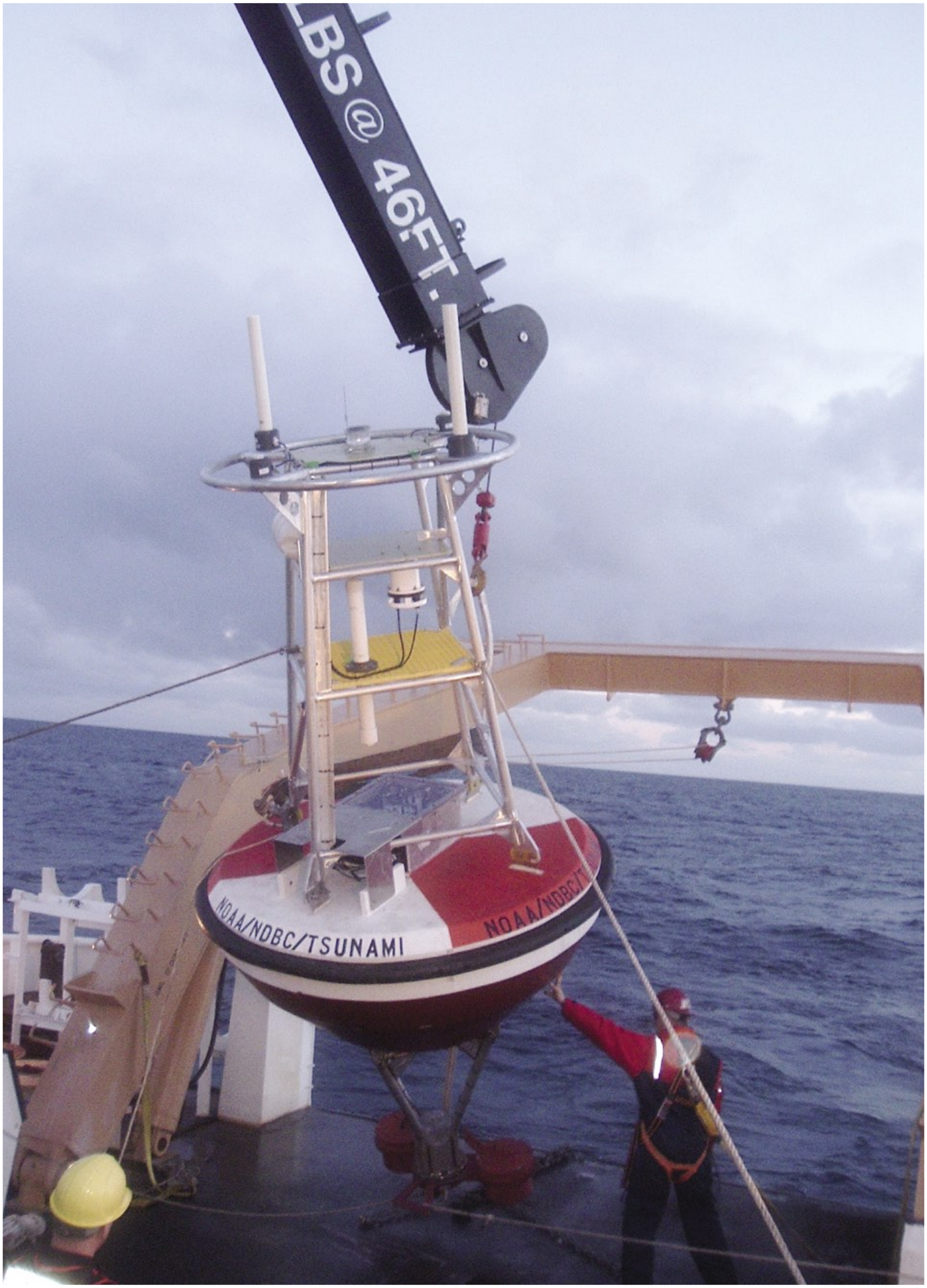
Figure 2: Approach to Implementing the U.S. Integrated Earth Observation System

- Interface with the user community and the decision support systems they use (requirements specification)
- Collect Earth observations (remote and *in situ*)
- Manage data (includes data archiving, access, processing, modeling, communications and delivery)
- Sustain and enhance capacity (includes research, training, and development)
- Deliver information (tailored to the needs of the user community)

Box 4: Functional requirements.

In following this approach for implementation it is important to have a clear understanding of the scope of the U.S. effort for developing an Integrated Earth Observation System. The following bullets describe the partnerships that will be critical for the success of the U.S. effort.

- The U.S. effort will be multi-disciplinary. It will take into consideration the interaction among multiple science disciplines, including physical, life and social sciences.
- The U.S. effort will be interagency. It will build upon existing systems and strategies to develop a framework for identifying gaps and priorities.
- The U.S. effort will link across all levels of government. The stakeholder capacity to use assessment and decision support tools for decision-making will be supported through education, training, research, and outreach. Building domestic user capacity is a key consideration.
- The U.S. effort will be fully integrated into a coordinated international effort. Environmental observations and science are international in scope and international cooperation is imperative both to the U.S. and global plans.
- The U.S. effort will encourage broad participation. Many entities (public, private, and international) acquire and use Earth observations. The scope of the integrated Earth observation system will encompass the needs of these entities including the commercial Earth observation data providers, value-added intermediaries, and commercial users.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ESTABLISHMENT OF A U.S. GOVERNANCE STRUCTURE

The joint OSTP/OMB guidance memorandum dated June 6, 2003, gave the National Science and Technology Council, through its respective agencies, the charge to "develop and implement a coordinated, multi-year plan to enhance data time series, minimize data gaps, and maximize the quality, integrity, and utility of the data for short-term and long-term applications." To this end, a standing Earth observation subcommittee of the Council's Committee on Environment and Natural Resources will be established. This Subcommittee, the United States Group on Earth Observations (US GEO), will develop strategies for efficient and streamlined operations for the U.S. Integrated Earth Observation System and will further the work accomplished by the Interagency Working Group on Earth Observations in leading and coordinating the implementation of this multi-year U.S. plan on Earth observations. This subcommittee will have responsibility for periodic assessment of the multi-year U.S. plan, as well as annual reports to the Committee on Environment and Natural Resources on progress and recommendations.

Consistent with the President's Management Agenda, Federal research and development investments for an integrated and sustained system of Earth observations will be managed as a portfolio of interconnected interagency activities, taking into account the quality, relevance and performance of each project. Working with the external stakeholder community, including industry, academia, and state, local, regional and tribal governments (consistent with the Federal Advisory Committee Act), this strategy will address not only planning, management and prospective assessment, but will also seek retrospective assessment of whether investments have been well directed, efficient and productive.

The agencies, through the Subcommittee (US GEO), will recommend priorities for investment for near-term, mid-term and long-term activities, recognizing that we may develop new requirements in addition to those already identified as critical for the societal benefit areas, and allowing for maximum flexibility as the system develops and coordination needs change. In addition, the Subcommittee will, over time, assemble its own benchmarks and metrics to assess the plan's relevance, quality and performance across societal benefits areas. The broad overlap of the societal benefits and the various agencies' missions is illustrated in Table 1, depicting agencies as users, providers, or both user and provider of relevant Earth observations.

The Subcommittee will continue to formulate U.S. positions and inputs into the Global Earth Observation System of Systems, taking into account the full range of U.S. policies and interests, and the requirements of the widest range of decision-makers, researchers, service-providers, the public, and other stakeholders worldwide.

It is clear from the data presented in Table 1 that a coordinated interagency approach to the Integrated Earth Observation System is imperative. The participating agencies have distributed responsibilities and requirements across the nine societal benefit areas. A sustained interagency effort will ensure that effectiveness and efficiency in achieving these benefits is maximized.

U.S. Agencies Related To Societal Benefit Areas

TABLE KEY

- P = primarily provides data
- U = primarily uses data
- B = uses/provides data

Societal Benefit Areas	DOC/NIST	DOC/NOAA	DOD	DOE	DHHS/NIEHS	DHS/FEMA	DOI/USGS	DOS	DOT	EPA	NASA	NSF	Tennessee Valley A.	Smithsonian	USAID	USDA
Weather		B	B	U	U	U	U		B	U	B	U	U	U	B	B
Disasters	U	P	B	U	U	U	B	U	U	U	B	B	U	U	U	U
Oceans		B	B	B	U	U	B	U	U	B	B	B		U	U	
Climate		B	U	B	U	U	B	U	U	B	B	B		U	B	B
Agriculture	U	P		U	U	U	P	U		B	P	B		U	B	B
Human Health	U	P		P	B			U	U	B	P	B		U	B	
Ecology	U	B	B	B	U		B	B		B	B	B		B	B	B
Water	U	B	B	B	U	U	B	B	U	B	B	B		U	B	U
Energy	U	P		B	U	U	B	P	U	B	P	U	B	U	U	

Table 1: U.S. Agencies as primarily provider, primarily user, or both provider and user of Earth observation data associated with the identified societal benefit areas.

POLICY, TECHNICAL AND FISCAL ASPECTS OF IMPLEMENTATION

Policy Aspects of Implementation

The strategy for implementing the U.S. Integrated Earth Observation System has three components: policy, technical and fiscal. The policy component identifies the aspects of Earth observations that will be defined as mandates or guidelines at the Federal level. Additionally, this policy component addresses data sharing and the identification of critical observations, and recognizes the requirement for decisions based on sound science, defined needs, and available options. The best way to generate knowledge is through science. The critical observations are the observations essential for sound science and decision-making, and are best determined through stakeholder involvement.

A. Data Sharing

The U.S. Integrated Earth Observation System will provide full and open access to all data in accordance with OMB Circular A-130. All data (subject to applicable national security controls and proprietary rights), shall be available for the operational, research, commercial, and academic communities with minimum time delay and at minimal cost. Commercial observation systems and observation data represent valuable national assets for the U.S. Integrated Earth Observation System. We encourage continued development of enhanced capabilities to meet evolving requirements in support of achieving societal benefits and to fulfill the intent of the U.S. Commercial Remote-sensing Space Policy (25 April 2003) and other applicable policies.

B. Critical Observations

The U.S. Integrated Earth Observation System will focus on collecting critical observations—elements considered of sufficient importance to mandate their collection based on their societal, economic, and scientific imperatives. Obtaining the appropriate metadata (data about the data, such as its quality and how it was acquired) will be an additional focus, enabling the effective use of all data collected. To illustrate this point, Table 2 shows a limited cross section of various observations and their relative level of importance to each societal benefit area. This table is not comprehensive and is intended only to provide a snapshot of overlapping benefits of selected observations.

Benefit Areas Related To Earth Observations

TABLE KEY

H = High level of importance to benefit area
M = Medium level of importance to benefit area
L = Low level of importance to benefit area

Earth Observations Note: This list of observations is not meant to be comprehensive	**Societal Benefit Areas**								
	Weather	**Disasters**	**Oceans**	**Climate**	**Agriculture**	**Human Health**	**Ecology**	**Water**	**Energy**
Land Elevation and Surface Deformation	M	H	L	L	M	M	M	H	L
Land Use/Land Cover (Crops, Forests, Urban, etc.)	M	M	L	M	H	H	H	M	M
Ecosystem Parameters (Health, Diversity, etc.)	L	L	H	H	H	M	H	M	L
Fire (Detection, Extent, Severity)	L	H	L	L	H	H	H	L	L
Soil Moisture	M	M	L	H	H	H	M	H	L
Ice and Snow (Cover and Volume)	M	M	M	H	M	M	M	H	M
Land and Sea Surface Temperature	H	H	H	H	H	H	H	M	H
River Runoff (Volume, Sediment, etc.)	L	H	H	H	H	H	H	H	H
Water Quality (Contamination, Spills, etc.)	L	H	H	L	H	H	H	M	L
Sea Surface Height/Topography	H	H	H	H	L	M	H	M	L
Ocean Current and Circulation	M	L	H	H	L	L	H	L	L
Ocean Salinity	L	L	H	H	L	L	H	L	L
Ocean Color (Chlorophyll, etc.)	L	L	H	L	L	H	H	L	L
Atmospheric Constituents (Ozone, Greenhouse Gases, Black Carbon, Volcanic Ash and other Aerosols, etc.)	L	H	M	H	L	H	L	H	H
Atmospheric Profiles (Temperature, Pressure, Water Vapor)	H	H	L	H	L	M	L	L	L
Wind Speed & Direction (Surface, Tropospheric, Stratospheric)	H	H	H	H	M	H	M	L	L
Cloud Cover (Properties, Type, Height)	H	M	M	H	M	L	L	L	L

Benefit Areas Related To Earth Observations

TABLE KEY

H = High level of importance to benefit area

M = Medium level of importance to benefit area

L = Low level of importance to benefit area

Earth Observations Note: This list of observations is not meant to be comprehensive	**Societal Benefit Areas** Weather	Disasters	Oceans	Climate	Agriculture	Human Health	Ecology	Water	Energy
Total and Clear Sky Radiative Flux	H	L	M	H	H	M	M	M	H
Solar Irradiance	L	L	L	H	L	M	M	L	L
Space Weather	L	H	L	L	L	M	L	L	H
Precipitation	H	H	M	H	H	H	H	H	H
Gravity, Magnetic Field, and Field Variations	H	H	H	H	L	L	L	H	L
Space Geodesy: Terrestial Reference Frame and Earth Orientation	H	H	H	H	H	L	M	H	L
Earthquake and volcanic activity	L	H	L	M	L	L	L	L	L
Geology (bedrock and surficial) and soils	L	H	L	L	M	L	M	M	M
Species (Occurrences, density, etc.)	L	M	H	H	H	H	H	M	L

Table 2: Relative importance of an illustrative list of Earth observations to the identified societal benefit areas.

Technical Aspects of Implementation

The technical component describes the architectural approach, noting that this system will be built upon existing and planned systems and will identify and document observation gaps and needs in the societal benefits areas. Currently, most of the data and information related to Earth observations are encompassed within the U.S. National Spatial Data Infrastructure, and integration of Earth observations will be implemented within that legal, policy, and institutional framework. The technical implementation component will establish the standards, protocols, and metadata for observation systems. The strategy will also recommend the optimum operating environment and support developing the associated human and institutional capacity.

The U.S. Integrated Earth Observation System builds upon current cooperation efforts among existing observation systems (including but not limited to the physical integration of observation systems on the same platform or at the same ground site, and by sharing space platforms and observation towers on the ground for various observations), processing systems, and networks, while encouraging and accommodating new components. Across the processing cycle from data collection to information production, participating systems maintain their mandates, their national, regional and/or intergovernmental responsibilities, including scientific activities, technical operations and ownership.

For required new components, the Subcommittee (US GEO) will recommend appropriate stewardship roles. The U.S. Integrated Earth Observation System participants will coordinate with commercial, academic, and other non-government organizations consistent with the Federal Advisory Committee Act.

A. Interoperability/Protocols/Standards

Standards (including metadata standards) and protocols will be followed for the successful implementation of the U.S. Integrated Earth Observation

System. These standards and protocols will address data and metadata access, interoperability, processing, dissemination, and archiving.

Interoperability will focus primarily on interfaces, defining how system components interface with each other and thereby minimizing any impact on affected systems other than interfaces to the shared architecture. Since interoperability agreements must be broad and sustainable, fewer agreements accommodating many systems are preferred over many agreements accommodating fewer systems.

To the maximum extent possible, interoperability agreements will be based on non-proprietary standards. Tailoring of standards (profiles) will be specified when standards are not sufficiently specific. Rather than defining new specifications, system implementers will adopt standard specifications agreed upon voluntarily and by consensus, with preference to formal international standards such as those of the International Organization for Standardizations (ISO).

B. Data and Information Assurance and Security

Services providing access to Earth observations data and products often include significant requirements for assuring various aspects of security and authentication. These range from authentication of user identity for data with restricted access, to notification of copyright restrictions for data not in the public domain, and to mechanisms for assurance that data are uncorrupted. The U.S. Integrated Earth Observation System will promote convergence on common standards for these various aspects.

C. Data and Information System Hardware/Software

New hardware capabilities will only be required to the extent that they fill a need for a dedicated function that is not currently provided or anticipated. From the overall system perspective, it is anticipated that several types of new or refocused data and information “centers” are possible, as follows:

- » Archive centers to acquire, preserve, and provide long-term access to Earth observation data.
- » Regional data centers to acquire and provide access to Earth observation data collected in specific geographic regions. These centers often collect a variety of physical, biological, and chemical ocean data that are used to support scientific, public, and commercial interests in the region.
- » Data assembly centers to obtain Earth observation data and provide access to it. They typically specialize in certain types of data, and often provide quality control and data products in their area of expertise.
- » Modeling centers to procure and synthesize observational data to produce products such as analyses, predictions, or hindcasts that may span a wide range of spatial and temporal scales.
- » High-performance computing centers to process anticipated high-volumes of data from next generation Earth observation systems.

Software capabilities are required to support the functions described elsewhere in this document including data and metadata management, data access, data transport, archive management, processing/modeling, quality control, and geospatial information systems, among others. These crosscutting data handling functions are in addition to software functions required to process observations.

D. Infrastructure/Bandwidth

The successful operation of the U.S. Integrated Earth Observation System will rely directly on the provision of a communications infrastructure sufficient to carry observations at sizes and rates ranging from point observations of a few hundred bytes to thousands of gigabytes. As a part of the inventory process that was begun by the Interagency Working Group on Earth Observations, a comprehensive sizing/timing study will be conducted to develop a multi-year communications plan. The communications plan will include milestones for rollouts of capability, including the infusion of next generation technology.

E. Human and Institutional Capacity

Support for developing human and institutional capacity is critical. The identification of user requirements and capacity gaps for the U.S. Integrated Earth Observation System should occur early in the implementation of the plan. Capacity building efforts should build on existing local, regional, national and international initiatives. Priorities include education, training, research and outreach.

Education creates the pipeline yielding the next generation of scientists, engineers, and technologists who will become the data providers, data users and innovators of the future. Education and outreach are also important to:

- ensure that decision makers at all levels understand the role of Earth observations in achieving societal benefits, and
- create a knowledgeable public that can engage policy makers in the complex, difficult and critical decisions encountered that will be made

The GLOBE program partnership[20] offers an excellent example of an international program with partners across technical, development, and aid agencies around the world. This partnership is a worldwide hands-on, primary and secondary school-based education and science program. The program has delivered results globally by training teachers and engaging primary and secondary level students in collection, observations, and analysis of environmental data. Unique to this program is the involvement of students around the world from both developed and developing nations where schools had been difficult to access.

Fiscal Aspects of Implementation

Implementation of the U.S. Integrated Earth Observation System requires specific prioritization of resources to ensure critical observation systems are developed or sustained. Prioritization of near-term Earth observation activities will be included in annual submissions to the Office of Management and Budget and the Office of Science and Technology Policy. To implement this Strategic Plan, the Subcommittee (US GEO) will be expected to identify budgetary priorities within the framework of Office of Management and Budget's research and development investment criteria (quality, relevance, and performance).

ARCHITECTURE FOR THE U.S. INTEGRATED EARTH OBSERVATION SYSTEM

The necessary functions of the U.S. Integrated Earth Observation System include data collection, data management, data discovery, data access, data transport, data archiving, processing, modeling, quality control, and others. The development of the integrated system will be based on the following key architectural principles:

- Supports a broad range of implementation options (driven by user needs), and incorporates new technology and methods;
- Addresses planned, research, and operational observation systems required for participants to make products, forecasts and related decisions;
- Includes observation, processing, and disseminating capabilities interfaced through interoperability specifications agreed and adhered to among all participants;
- Records and stores observations and products in clearly defined formats, with metadata and quality indications to enable search and retrieval, and archived as accessible data sets; and
- Provides a framework for securing and sustaining the future continuity of observations and the instigation of new observations.
- Builds on existing systems and historical data, as well as existing assessments of observational needs in the specified societal benefit areas.

The Federal Enterprise Architecture Framework[21] is a conceptual model that defines a documented and coordinated structure for crosscutting businesses and design developments in the government. The Subcommittee (US GEO) will develop the architecture for the U.S. Integrated Earth Observation System in accordance with the Federal Enterprise Architecture Framework.

The integrated system architecture description will be a “living” document, continuously revised under the direction of the governance process established, to account for new and evolving requirements and capabilities to meet those requirements.

INTEGRATION OF EARTH OBSERVATION SYSTEMS

The Earth is an integrated system. Therefore, all the processes that influence conditions on the Earth are linked, and impact one another. A subtle change in one process can produce an important effect in another. A full understanding of these processes and the linkages between them requires an integrated approach, including observation systems and their data streams. Figure 3 provides a visual overview of the integration process.

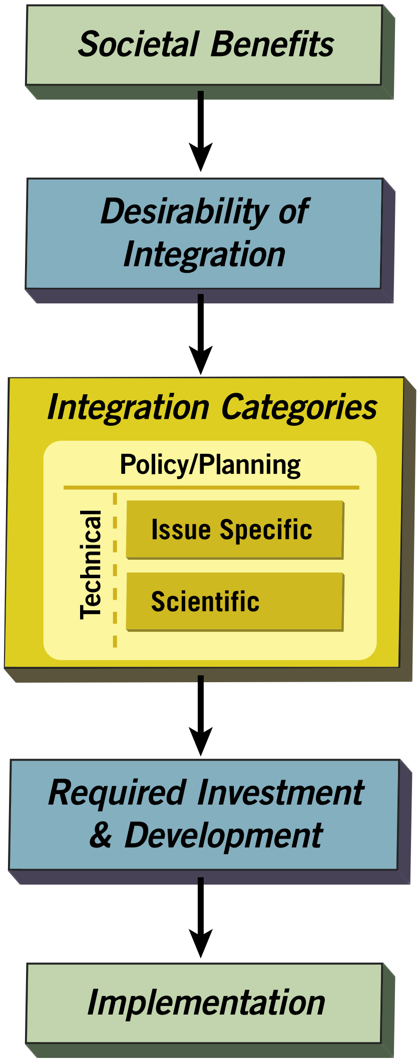


Figure 3: Overview of the Integration Process

Integration is necessary and appropriate for those systems where the parts are well understood and the benefits outweigh the added scientific and/or financial costs.

The process of integration begins with these key questions:

- Which observation systems functions are related to the identified societal benefits (a question that requires understanding user needs)?
- What level of integration is desired and cost-effective?
- Which observation systems functions will be integrated?

- Which observations need to be integrated?
- What tools and methods will be used to accomplish the integration of the observation systems functions?
- What plans need to be developed and implemented?

This plan starts to answer these questions by viewing integration from four perspectives:

- policy and planning integration,
- issue and problem focused integration,
- scientific integration, and
- technical systems integration.

A. Policy and Planning Integration

Policy and planning integration addresses the identification of and focus on specific societal benefit areas. In the past, Earth observation systems (research and operational) typically have been deployed for one purpose, and then adapted for other applications. In some cases, this approach has worked well, where observation systems were flexible to accommodate new users. In others, the original system design and life cycle planning did not anticipate or were unable to address secondary or unforeseen user applications, either in terms of the technical and scientific specifications or the availability of operational capabilities and capacities. The framework developed in this plan helps to lay the foundation for an integrated approach to policy development for Earth observations systems that will maximize these synergies.

B. Issue and Problem-focused Integration

Issue and problem-focused integration addresses how the U.S. Integrated Earth Observation System addresses a particular issue. In order to get from observations to societal benefits, several links in a chain need to be forged. These links include data analysis, research, process modeling, and finally development of decision support tools. The development of a decision support tool for application requires the integration of several chains of investigation of various topics. Effective education, communication, and outreach are crucial links among operations, science, and society. The results of Earth observations need to be described in common, consistent, and understandable terms that are useful for decisions at all levels.

Drought, for instance, impacts all of the nine societal benefit areas. The assessment and analysis of drought depends on measurements across many time and space scales, as shown in Table 3. The weekly drought monitoring reports distributed to the public, with contributions from various agencies, show how this Earth observation information is integrated across all societal benefit areas. On monthly time-scales a subset of the Table 3 data and information from three countries (Canada, Mexico, and the United States) are integrated. International integration is still in an experimental stage and considerable data and information have yet to be incorporated into comprehensive drought assessments.

The urban environment is an example where multiple observations and tools are required. Physical processes and environmental conditions in our urban and suburban regions directly impact over 70% of the U.S. population.[22] Mapping, modeling, and monitoring our urban settings allows for better future design decisions that minimize the physical influences of the urban environment on the natural surroundings.

Societal Benefit Areas	Important Observations	Time-scales of Interest
Agriculture	Soil moisture	Weekly
Energy	Reservoir and lake water levels	Monthly
Water resources	Ground water and lake levels/water quality	Seasonal to decadal
Weather	Circulation, water vapor	Daily to weekly
Climate	Boundary conditions	Weekly to decadal
Ocean resources	River flow	Monthly
Human health	Water availability/quality	Daily to seasonal
Ecology	Water availability/quality	Weekly to decadal
Disasters	Vegetation and wildfires	Daily to decadal

Table 3: Examples of How Drought Integrates Across Societal Benefit Areas

C. Scientific Integration

Scientific integration addresses those parts of an unresolved problem that require information across the societal benefit areas or across scientific sub-disciplines within each of the areas. An important element of scientific integration includes modeling of Earth processes.

Our understanding of Earth processes begins with scientific research. It is important that research continue to refine existing models and develop new paradigms. These models can be useful tools in defining scientific integration priorities. In some cases, research evolves in a straightforward manner to operational applications used in regularly scheduled forecasts and projections. However, when different models for the same process give differing answers, we know we have more work to do. A broader set of observations, targeted experiments, or better knowledge of underlying mechanisms may be required to aid our understanding.

Scientific integration can be illustrated by using the example of sea level change. While measuring sea level change only requires observations, understanding why sea level is changing requires scientific integration of data from various sources. Measurements of global sea level data are needed from tide gauges and satellite altimetry. Additional data concerning the causes of sea level change include information related to the thermal expansion or contraction of the sea, which can be acquired through a variety of platforms and instruments (such as ships, satellites, buoys, expendable bathythermographs, acoustic tomography, etc.) and information related to land-ice accretion or ablation (acquired through satellites and *in situ* measurements). Data on rates of change of stored water on land and on coastal topography are also important. To aid our understanding, all of these data and information can be integrated into land-ice models, ocean models, land-runoff models and ultimately into even broader integrated sea level models. Ongoing comparisons of model predictions with observations help improve and validate these models.

D. Technical Systems Integration

Technical systems integration addresses the coordination of observation system technology and data management systems that enable research and operational applications. Across many of the societal areas, there are common challenges that would benefit from an investment in integrated solutions. Salient among these are the following (with associated examples):

- Information technology integration: control of the data flow (communications), processing (analysis), standards and protocols. This includes the data protocol integration necessary for distribution of data to a variety of user applications, such as open data formats for processing data.
- Observation platform and observation site integration: the infrastructure and the underpinning of observation systems. This platform and site integration could include: the physical integration of observation systems on the same platform or at the same ground site, such as sharing space and suborbital platforms and observation towers on the ground for various observations; and maintaining and upgrading major *in situ* networks in an orderly way.
- Multifunctional integration: using observation platforms not only for Earth observations but also for communication. For example, the Climate Reference Network in the U.S. uses the GOES satellite to transmit real-time benchmark climate observations for a variety of applications including weather and climate.
- Scientific and operational integration: the assurance of the continuity of the observations. Mechanisms need to be developed to assure the effective transition of observation systems from research to operational status, where appropriate.
- Integration considerations must also address observation system evolution. Observation system upgrades, new systems, system replacements, etc. all need to be considered in the context of a structured system integration approach. The significance and role assigned to models and other decision support tools in the integration process must also be considered. In some cases observation system experiments can be conducted to provide an objective, quantitative assessment of "how much something helps and contributes." However, objective analysis is not possible in every case, and a well-disciplined subjective evaluation may be necessary.

NEXT STEPS IN IMPLEMENTATION

Both the establishment of an appropriate organizational structure and the development of a common system architecture are critical to the successful implementation of this Strategic Plan. The steps required to accomplish both are described below.

A. Establishing the U.S. Integrated Earth Observation System Organizational Structure

Three organizational steps must be accomplished:

- Establish formally the U.S. Group on Earth Observations (a subcommittee of the NSTC Committee on Environment and Natural Resources and successor organization to the Interagency Working Group on Earth Observations).
- Commit necessary agency resources to accomplish the governance functions.
- Implement the approved governance functions of the Subcommittee (US GEO). The following is an initial list of governance functions that will be finalized in the Terms of Reference for the Subcommittee.
    - Establish a process for interaction with external stakeholders, consistent with the Federal Advisory Committee Act.

- Identify and vet requirements, both within the government and with external stakeholders, including continued review and assessment of existing and emerging societal benefit areas, architecture/ data utilization, and capacity building/ international cooperation.
- Establish a process for prioritization of observation system investments.
- Submit an annual report to the National Science and Technology Council that includes near-term priorities for the upcoming budget year at the end of each calendar year. Current near-term opportunities are described in Appendix 2.
- Submit to the National Science and Technology Council the mid- and long-term activities before April of each year.
- Establish assessment mechanisms and metrics to validate quality, relevance, and performance.
- Assess current and potential new societal benefit areas.
- Refine and clarify the roles and opportunities for commercial observation networks and for international systems in achieving the vision of the U.S. Integrated Earth Observation System
- Establish processes for standards, interoperability, and an open, scalable architecture.

B. Developing a Common System Architecture

A common system architecture is a necessary key enabler for the U.S. Integrated Earth Observation System. The following are near-, mid-, and long-term architectural steps towards the vision for the system.

The near-term architectural steps are:

- Establish multi-year process to develop and sustain the Federal Enterprise Architecture Framework for the U.S. Integrated Earth Observation System. Complete an inventory of the systems included in the U.S. Integrated Earth Observation System.

- Prioritize the list of functional and performance requirements reflected in box 4, page 28.
- Further refine the initial mid- and long-term architectural steps.

The initial list of mid- and long-term architectural steps includes:

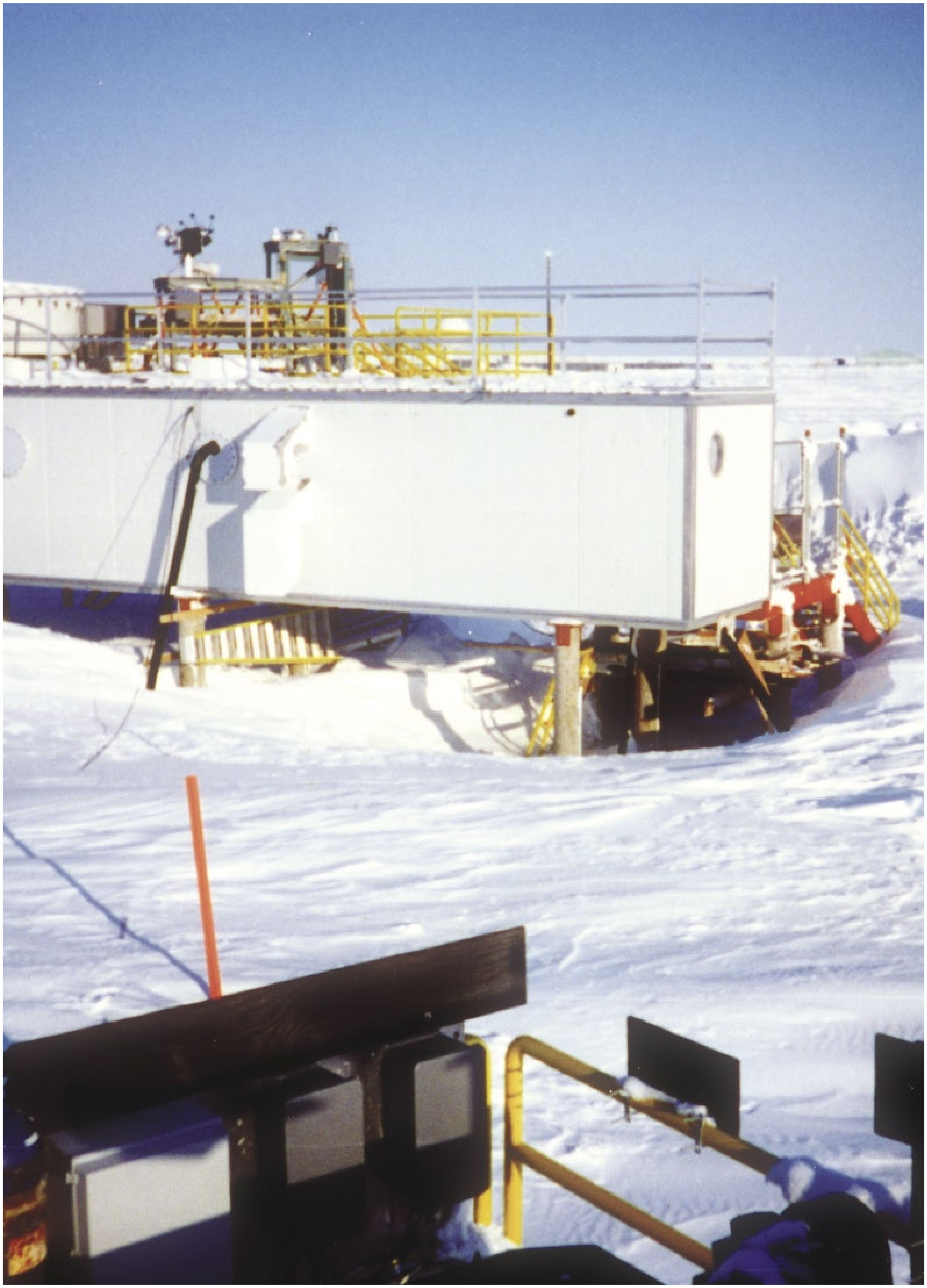
- Identify candidate system solutions, consistent with the architecture framework, to deliver Earth observation information in support of the selected societal benefit areas
- Update and maintain inventory of systems
- Continue cooperation with the international Earth observation community and the Global Earth Observation System of Systems

The Subcommittee (US GEO) will regularly review and assess the implications of scientific and technological advances, particularly innovations that change the structure and approach to the architecture.

CONCLUSION

The U.S. Integrated Earth Observation System will provide the nation with a unique and innovative perspective on the complex, interacting systems that make up our planet. This Strategic Plan defines the purpose and vision. It outlines a practical approach with a societal benefits focus, identifying key issues in integration and governance. This plan highlights specific opportunities ripe for near-term action by the participating agencies, and identifies the next steps in implementing the governance and system architecture.

Like the Earth, the U.S. Integrated Earth Observation System will continue to evolve. An evolving system, taking into account emerging technologies and scientific advances, is necessary to meet the changing needs of society. Implementing the U.S. Integrated Earth Observation System represents an exciting opportunity to make lasting improvements in U.S. capacity to deliver specific benefits to our people, our economy and our planet.



APPENDIX 1:

Near-term Opportunities

Because there is currently no comprehensive and integrated strategy for communicating existing data, data management is highlighted as both an overarching need, and the necessary first near-term action for this integrated system. Several other near-term opportunities are identified in this section, and programs implemented to address these opportunities will do so within the framework of the Office of Management and Budget's Research and Development Investment Criteria (Quality, Performance, and Relevance).

Clear plans have been developed for these opportunities, which are relevant to national priorities, agency missions, and customer needs. The identified observations needs are high-priority and multi-year in their goals, with tangible results easily identified. These potential outcomes cut across all societal benefit areas identified in this strategy.

A. Data Management

Requirement/Need: The U.S. needs a comprehensive and integrated data management and communications strategy to effectively integrate the wide variety of Earth observations across disciplines, institutions, and temporal and spatial scales.

Why now? There are three urgent needs for data management:

- New observation systems will lead to a 100-fold increase in Earth observation data.
- Individual agencies' current data management systems are challenged to adequately process current data streams.
- The U.S. Integrated Earth Observation System, linking the observations and users of multiple agencies, compounds these challenges.

Data management is a necessary first step in achieving the synergistic benefits from the U.S. Integrated Earth Observation System described in this document.

Outcome: The expected outcome includes data management systems that are well-linked and support the full information cycle from observation acquisition to information delivery. At a minimum, the U.S. Integrated Earth Observation System must address these urgent needs by focusing on specific data management solutions:

- Data and products will be made readily available and easily accessible by applying data management systems.[23] This activity will include standardizing vocabularies across agencies and developing browsing and visualization systems. Interoperability is achieved through protocols and standards agreed upon by the member agencies. These tools will enable users to effectively locate data and information relevant to their needs.

- The quality of Earth and space-based data will be improved by building on the approaches used by previous scientific data stewardship projects (such as the satellite pathfinder data reprocessing projects) and model reanalysis projects (such as North American Reanalysis, Global Reanalysis, and Global Ocean Data Assimilation Experiments). The output of these projects can help achieve important objectives of many users: improved data integration, quality, and granularity.
- Metadata will be critical to the success of any integrated data management system. Technological solutions are currently available to maximize metadata usage.[24] Current efforts are limited to pilot projects. Emphasis must be focused on a dedicated commitment to implement these software solutions for all science and technology needs.

B. Improved Observations for Disaster Warnings

Requirement/Need: Disasters afflict all regions of the world, and improved global disaster reduction and warning is a shared, global need. Geo-hazards such as earthquakes, volcanoes, landslides and subsidence are examples of hazards where improved monitoring can provide improved forecasting. We need a complete monitoring system that supports risk assessment surveys, providing information critical to improved mitigation strategies and providing systematic and sustained monitoring of regions at risk. The greatest set of unmet observational requirements is for systematic, widespread coverage. This can best be delivered by maintaining and modernizing existing *in situ* atmospheric, ground-based, and ocean observation systems and by enhancing our capabilities in synthetic aperture radar (SAR) and interferometric synthetic aperture radar (InSAR) systems.[25] Applications of InSAR include robust observations of surface deformation, which complements time-continuous observations of deformation derived from GPS networks. Other major SAR hazards applications include monitoring sea ice, oil slicks, and inundation from flooding.

Why now? In many cases, *in situ* airborne and ground-based systems are not being maintained to meet research and operational objectives and are not being modernized to meet their research and operational potentials, even though plans exist for development of these systems. In the next few years, the governments of Canada and Japan will launch advanced synthetic aperture radar satellites, and there is a pressing need to work in advance on data access. Although we have demonstrated the capability through limited sporadic synthetic aperture radar (SAR) data, we currently have no operational radar satellite system that could truly, in a real-time manner, reduce hazards, help mitigate disasters, and realize goals of saving lives and reducing damage.

Outcome: Improved ground-based disaster research and warning networks, incorporating more systematic use of InSAR and exploitation of SAR's all-weather capability, will:

- access data from existing and planned synthetic aperture radar systems by the U.S., Canada, Europe and Japan;
- improve rapid observation of damage and landscape change caused by the geohazards;
- provide better monitoring of land and sea ice, oil slicks, and flooding;
- enable better forecasts, preparations, and more rapid responses to disasters; and
- broaden access and distribution of key data sets to the relevant communities of scientists, operational agencies and decision-makers.

C. Global Land Observation System

Requirement/Need: We need a comprehensive and sustained land observation system to support land management decisions. These data are currently broadly used in a wide variety of research and management areas such as:

- the influence of land cover on water quality,
- the extent of urban sprawl, and
- how best characterize biodiversity, agricultural production, forest and vegetation health, fire management, etc.

Why now? The main source of our current land observation data, Landsat, is facing technological obsolescence, mission life limitations, and funding challenges. The Landsat Data Continuity Mission has faced delays throughout its programmatic history.

Potential Outcome: A global land observation system that provides sustained national and global observations of land cover and high-resolution topography from satellite, airborne and surface systems to complement the historical archive. Examples of capabilities this system should provide included:

- High resolution digital topographic data including digital elevation maps
- Continued collection and/or acquisition of remotely-sensed land cover data
- Access to commercial land remote-sensing imagery

D. Sea Level Observation System

Requirement/Need: We need an operational sea level observation system to provide comprehensive and sustained sea level data and prediction of future changes in sea levels. With millions of people living near the coast, changes in sea level will be a concern to life and property, especially for barrier islands, coastal cities, river deltas, and islands. The storm surge generated by hurricanes, typhoons, and cyclones would exacerbate the effects of potential sea level rise. Improved data on global sea level rise is a high priority issue requiring strengthened international cooperation in the sustained collection of high-quality observations as the basis for sound decision-making. Currently there is no integrated operational ocean altimetry system.

Why now? We have the opportunity to transition satellite altimetry research capabilities to operational use (Jason-1). Future uninhabited aerial vehicles (UAVs) and other suborbital systems will provide unique opportunities to monitor processes and change in coastal regions and wetlands. Lack of timely action may prevent the effective transition of this capability to operational status. Globally averaged sea level could rise 9 to 88 centimeters over the coming century, impacting coastal infrastructure investments that are being made today.[26] Alaska is already facing relocation of over 100 villages due to coastal erosion and reduced sea ice cover.[27] Critical measurements are needed immediately to validate models to properly project sea level.

Outcome: The outcome is an operational sea level observation system that allows us to:

- Determine the rate of change in global sea level
- Understand the interaction of factors that cause sea level rise
- Predict future state of sea level and its impacts on coastal areas

E. National Integrated Drought Information System

Requirement/Need: Drought is a threat to the economic stability and prosperity of the Nation, and is having a $6-$8 billion annual impact.

Why now? We are facing the worst severe drought consequences in the western United States in 70 years.[28] There is an urgent national interest in better information on drought. Recently, the Western Governors' Association developed a set of requirements, through a broad-based team of Federal and nonFederal partners, for a National Integrated Drought Information System. These requirements were developed in conjunction with the National Drought Policy Commission's report to Congress and the pending Drought Preparedness Act before Congress. In addition, in 2004, the Committee on Environment and Natural Resources Subcommittee for Disaster Reduction acknowledged its seriousness by including it as one of its eight "Grand Challenges."

Outcome: The National Integrated Drought Information System represents a comprehensive, user-friendly, web accessible system to serve the needs of policy and decision-makers at all levels—local, state, regional, and national—concerned with U.S. drought preparedness, mitigation, and relief/recovery. Research efforts seek to improve drought-related observations such as soil moisture as envisioned in National Aeronautics and Space Administration's Hydros mission. Improved drought prediction is a main emphases and outcome in National Oceanic and Atmospheric Administration Program Plans for Climate-Weather Connections Research and Climate Prediction, and are consistent with coordinated interagency efforts, with

Academic partners, to develop an integrated Earth System Modeling Framework.[29]

F. Air Quality Assessment and Forecast System

Requirement/Need: Understanding air quality and its influence on people and the environment requires enhanced surface-based observations. Existing surface monitoring networks must be integrated with air quality observations from other platforms, including satellites, ships and aircraft, and used to develop and evaluate improved predictive models and decision support tools.

Why now? Despite dramatic improvements in air quality in the United States over the last 30 years—a period in which our population grew 39 percent, our energy consumption grew 42 percent, and our economy grew 164 percent—air quality problems have grown in many areas of the world, particularly in some fast-growing developing countries. Even with continuing air quality improvements in the United States, over 100 million people live in U.S. counties that exceed National Ambient Air Quality Standards.[30] It is well known that poor air quality is harmful to the health of both adults and children.

Potential Outcome: An enhanced observational system integrated with modeling and decision support tools will:

- » Improve the ability to forecast air quality across large parts of the country (and in other parts of the world) for which forecasts are not currently available
- » Provide better information about emissions and transport mechanisms on regional to the international scales

- Provide important information to help the public avoid harmful exposures and to help air quality management better manage air pollution episodes over the short and long terms.

APPENDIX 2:

Societal Benefit Area Technical Reference Report Summaries

Preamble

This Appendix provides summaries of detailed technical reference reports for each societal benefit area. These technical reports were written by interagency working teams as part of the development of the Strategic Plan for the U.S. Integrated Earth Observation System. The purpose of the technical reports was to: 1) provide the state of Earth observations in each of the societal benefit areas; 2) identify what observations are currently underway 3) identify observational gaps and research needs, and 4) describe how these gaps are being addressed. The interagency working teams are continually updating the reports and incorporating comments from the public and scientific community, both inside and outside the Federal government. As such, these documents are not statements of U.S. Government policy, but are “living” documents, for reference throughout the process of coordinating our Earth observations into a truly integrated system. The associated technical reference documents may be accessed in their entirety on the Interagency Working Group on Earth Observations website at http://iwgeo.ssc.nasa.gov.

This appendix provides an Executive Summary of those technical reports, and is not intended to be an exhaustive reference. It is divided into nine sections, each summarizing the observations for a benefit area, starting with the most mature system, Weather Forecasting. The benefit areas not only vary greatly in maturity of observation systems, but also by their very nature—for example weather forecasting is vital to every societal benefit area. On the other hand, Human Health and Well-Being relies on observations and the resulting data products from across the set of benefit areas. There are, however, some common threads across all benefit areas as discussed below.

Users of Observations

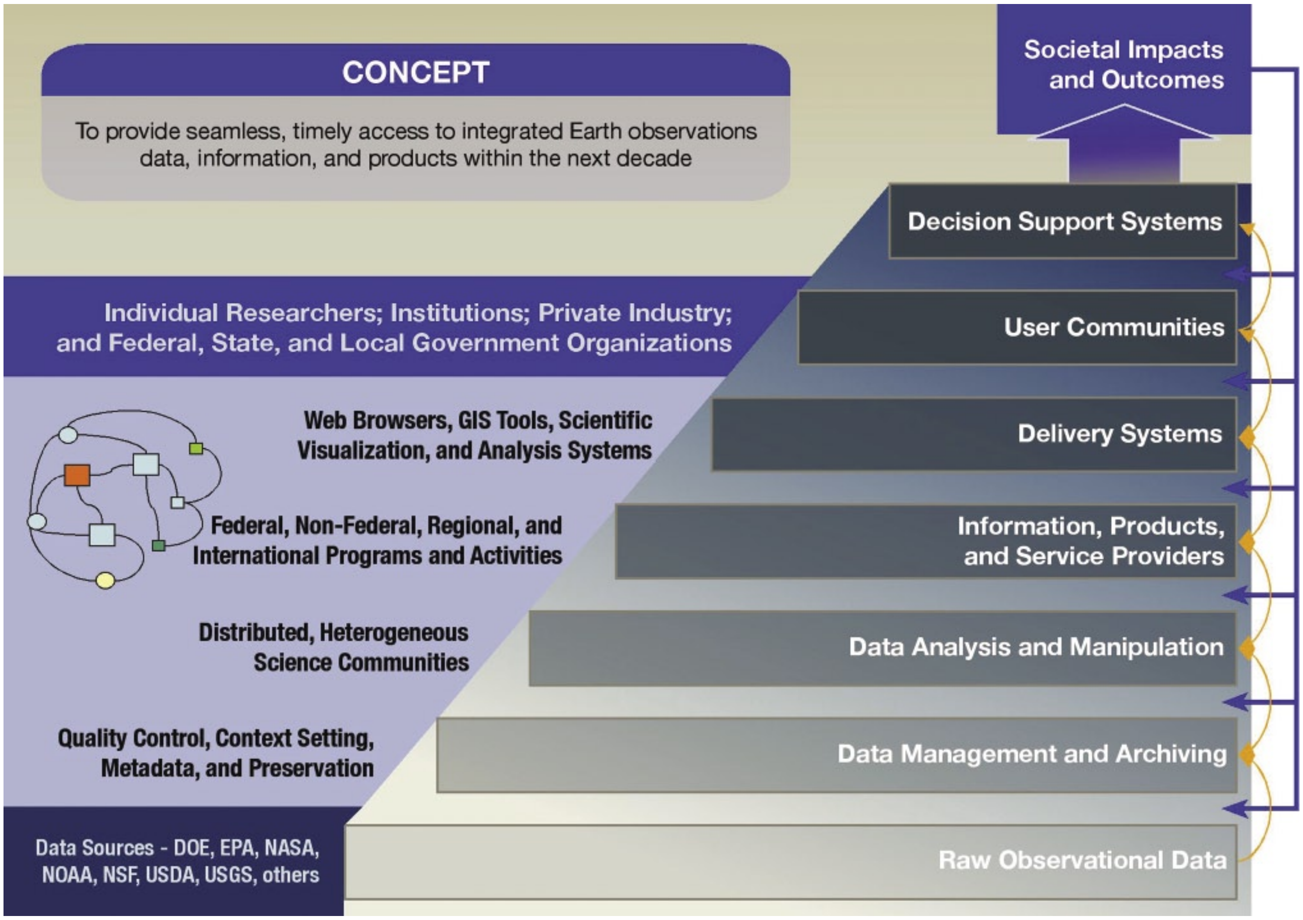
The beneficiaries of improved Earth observation will be society as a whole. However, in order to assess the efficacy of existing systems and identify gaps and future needs, we first must understand who the critical users are, and identify their needs. In the context of the nine societal benefits areas, these groups are:

> **End users** include the general public, the commercial sector and authorities with responsibility, for example, for managing the distribution and quality assurance of resources.
>
> **Scientists, managers, and policy makers in advisory, service and regulatory agencies** who need to make informed decisions on predictions of future conditions, respond to environmental changes and disasters in real time, develop accurate assessments and simulation tools to support decision-making, and run operational forecast and modeling centers.

Research scientists whose research is directed toward improving our understanding of the physical, chemical, biological, and ecological relationships that define our Earth system.

Integrated Data Transformation

An integrated Earth information system must provide for a seamless link between the providers and users of information systems. The following figure summarizes the issues in terms of transformations of raw observational data from many sources, from the long term record of observations, from data collected as part of research investigations, to highly precise continuous observations, to new types of data from improved observation systems. Such data require a comprehensive and reliable data management archive, coupled with tools to derive information products, a system for distribution, support for user interactions with the information products, and decision support tools that provide for user feedback to maintain and improve the end-to-end system. Observation systems must provide for integration of the data in the full end-to-end system that meets the requirements for: 1) stringent standards of calibration, sampling and accuracy necessary for useful data; 2) stability to maintain ongoing data archive; and 3) continued improvement through technical advances and user feedback.



Maintenance of Existing Systems and Data Collections

A critical challenge across all benefit areas is to maintain and operate observing capabilities and existing data archives. Progress in Earth observations will come in part from new capabilities and information. However, without the simple maintenance or enhancement of existing systems, for example, stream flow gauges for water monitoring and continuity of Landsat capabilities , progress will be spotty at best. Stability of observing systems is another important issue—we need to ensure that there will not be gaps in, for example, continuous satellite measurements. A third critical issue is the maintenance of observational records at all levels to allow scientists to evaluate the effects of change in, for example, air quality and or drinking water quality. Other key variables requiring maintenance include, for example, monitoring of disease, population characteristics, food production and distribution. Since the value of existing datasets greatly increases as the record is extended over time (for example, weather and climate data), it is imperative that existing capabilities be maintained and improved, while at the same time new requirements are incorporated.

Section 1: Improve Weather Forecasting

1. The State of Earth Observations for Weather Forecasting

The state of Earth observations for weather forecasting is the most mature observing system in the United States. As described in a recent National Research Council report, provision of weather services within the U.S. has evolved, over the past 40 years, from an almost exclusively governmental function to one carried out by the public sector (a combination of Federal, state, and local government agencies), the private sector, and academia. Partnerships exist at all levels to support meeting the weather needs of an increasingly diverse user community.

On the Federal level, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (also known as the Office of the Federal Coordinator for Meteorology (OFCM)) ensures the effective use of Federal meteorological resources by leading the systematic coordination of operational weather requirements and services, and supporting research, among the Federal agencies. Fifteen Federal agencies are currently engaged in meteorological activities and participate in the OFCM's coordination and cooperation infrastructure. Each year, OFCM prepares The Federal Plan for Meteorological Services and Supporting Research for the next fiscal year. This Congressionally mandated plan is a one-of-a-kind document, which articulates the meteorological services provided and supporting research conducted by Federal agencies. The Fiscal Year 2004 plan can be found at http://www.ofcm.gov/fp-fy04/fedplan.htm.

2. What Can We Observe Now?

The U.S. uses both remote-sensing and *in-situ* observation systems to collect required weather observations. Earth observation satellites provide an inherent wide area observation capability, non-intrusive observations, uniformity, rapid measurements, and continuity. *In-situ* observation systems provide measurements unobtainable from space, measurements complementary to those from space, and validation of satellite measurements. Weather information providers need observations from both types of systems to provide required weather forecasts. Major observational infrastructure investments by NOAA, NASA, FAA, and DOD provide the bulk of the currently deployed U.S. weather observing capabilities. The U.S. has an impressive space-, surface- and air-based weather observation infrastructure. For example, NOAA's catalog of observing systems is contained in the Strategic Direction for NOAA's Integrated Global Environmental Observation and Data Management System. Also, NASA describes its Earth observing systems within its Destination Earth website (http://www.earth.nasa.gov).

3. What Can't We Observe Now?

The box to the right illustrates the capabilities necessary for improving weather observing. Major gaps affecting weather forecasting improvements exist in two broad areas: exploiting weather information that currently exists, and improving that existing information. Within these two broad areas, there are five sub-categories of gaps in weather information that can be addressed by the U.S. Integrated Earth Observation System:

Weather Forecasting Functional Requirements:

- Increased coverage and resolution of observations
- Observations of environmental elements not presently observed
- Improved timeliness, data quality, and long-term continuity of observations
- Integrated multi-purpose observing systems and networks that allow rapid dissemination of weather information

Observational Lack of complete global observational coverage of the atmosphere, land, and oceans (for example, poor resolution, inadequate quality) inhibits development and exploitation of extended-range products. The following critical atmospheric parameters are not adequately measured by current or planned observing systems: wind profiles; vertical profiles of moisture; precipitation; thermal profiling of the ocean mixed layer; soil moisture; surface pressure; and snow equivalent-water content.

Modeling Inadequate aspects of scientific modeling (data assimilation, numerical weather prediction, and statistical post processing) limit the accuracy and reliability of weather forecasts and warnings. Numerical weather prediction (NWP) models have gaps in the following categories of data that increase uncertainty and reduce model accuracy: vertical profiles of moisture flux; coverage of tropical land areas and ocean areas; measurements of clouds, precipitation, and ozone; rigorous calibration of remotely-sensed radiances.

Decision Support Tools Decision analysis in disparate areas needs more than an accurate weather forecast. Techniques are needed to tailor those forecasts to specific applications to achieve full value.

Information Technologies Telecommunication and computer-processing gaps limit observations exchange, scientific collaboration, and dissemination of critical information to decision-makers and the general populace. Also, full implementation of new observing systems technologies is challenging due in part to a lack of structure to facilitate transition of research technologies to operational use in all components of the end-to-end weather-information services system.

Education and Training With improvements in all facets of producing and delivering weather information, parallel improvements in education and training processes are necessary to ensure full user exploitation of that information.

A recent article in the Bulletin of the American Meteorological Society, listed warm-season quantitative precipitation forecasts as the poorest performance area of forecast systems worldwide. This report illustrates the gaps and challenges facing the national and international weather forecasting communities. Key gaps were found in understanding scientific processes, observations, and data assimilation. Specifically:

Scientific processes Knowledge of environmental aerosols may prove necessary for properly representing cloud microphysical processes, but there are no efforts underway to provide routine observations of aerosols or even to provide a systematic research assessment of the forecast sensitivity.

Observations Observations on the scale of the events being forecast (for example, summer thunderstorms) are limited to those available from surface mesonets, profilers, radars, and geostationary and GPS satellites. While useful, these observing systems do not provide certain key pieces of information required by models. For example, the quality and vertical resolution of geosynchronous satellite data over heterogeneous continental backgrounds remains unacceptably low. Distant radars overshoot the boundary layer while nearby radars leave a "cone of silence", and surface mesonets provide no information about the free troposphere unless augmented with profiling devices.

> **Data assimilation** Data assimilation may be the most critical path through which advances in forecasting convective precipitation will be modulated. Two glaring gaps exist here: (1) a serious deficiency in human resources working on data assimilation, and (2) a large fraction of current observations are not being assimilated into today's models.

Addressing these challenges, the USWRP recommends a tightly knit implementation plan addressing basic research, advanced development (observations, assimilation technologies, and forecast systems), and experimental forecast demonstrations (with emphasis on verification metrics that are relevant to and understood by the general populace).

4. How are we Addressing Gaps?

The U.S. is addressing gaps in weather forecasting in three broad areas: plans, programs, and research.

Plans NWS has published two plans that form the basis of improving weather information within the U.S.—the NWS Science and Technology Infusion Plan (STIP) and the NWS Service Improvement Plan (NSIP). The NWS STIP: looks into the future and explains how science and technology may evolve NWS products and services; defines long-term strategies, objectives, and programs; and illustrates how the NWS plans to take advantage of scientific opportunities beyond the next ten years. The NSIP translates the grand vision of the NWS STIP into specific customer service improvements in the areas of aviation, climate, fire weather, hydrology, marine weather, health (for example, air quality), and homeland security.

Internationally, the WMO Expert Team on Observational Data Requirements and Redesign of the Global Observing System (GOS) has developed a vision for the GOS of 2015, which includes an observation component (with both remote-sensing and *in-situ* systems), and a data management component. This vision document provides a prioritized list of critical atmospheric parameters that are not adequately measured by current or planned observing systems. Those parameters in order of priority are:

Wind profiles at all levels

- Temperature profiles of adequate vertical resolution in cloudy areas
- Precipitation
- Soil moisture
- Surface pressure
- Snow equivalent water content

Programs Two new operational weather satellite systems—the National Polar-orbiting Operational Environmental Satellite System (NPOESS) and the Geostationary Operational Environmental Satellite-R (GOES-R)—will replace NOAA's current polar and geostationary satellites in 2009 and 2012, respectively. Both will provide improved technologies to support the detection and monitoring of severe weather, tropical cyclones, volcanic eruptions, and volcanic-ash clouds. These instruments will have improved spatial and temporal resolution, and will include a wider range of spectral bands than current U.S. polar-orbiting systems, although some bands currently available and used for fire detection will either be absent or too sensitive on the NPOESS equivalent for fire detection during daytime.

Other weather-related future solutions include expansion of the commercial aircraft Meteorological Data Collecting and Reporting System (MDCRS) globally, and more use of local carriers, expanded deployment of surface-based radar wind profilers to observe the atmospheric boundary layer, development and deployment of arrays of phased-array radars to significantly increase the quantity, quality, and timeliness of weather information during extreme weather events. In addition, operational deployment of unmanned aerial vehicles will enable routine *in situ* monitoring of the vertical distribution of several atmospheric parameters over wide regions, including remote areas of the globe not currently accessible. The DOT Intelligent Transportation Systems Program and NOAA are working to expand the collection and integration of surface-based observing systems, particularly as it pertains to commerce and surface transportation. Two initiatives in particular, the Nationwide Surface Transportation Observing and Forecasting System (also known as Clarus) and Vehicle Infrastructure Integration, are exploring the exploitation of land- and vehicle-based technology to collect additional weather data.

Research There are several collaborative research and development activities focused on improving operational weather forecasting capabilities. While this is not an exhaustive list of research programs, it illustrates the national focus on improving weather forecasting to benefit society.

First, through the Joint Center for Satellite Data Assimilation, NOAA, NASA, and DoD are developing common NWP model and data-assimilation infrastructure for:

- Accelerated development of assimilation algorithms for current operational satellite soundings from GOES, POES, and DMSP
- Rapid assimilation of programmed operational (CrIS, ATMS, and VIRS on NPOESS) and research satellite data (from QuickSCAT, TRMM, and MODIS) into operational models

Second, NOAA is working with NASA's Short-term Prediction Research and Transition Center to accelerate the infusion of NASA science and technology to help meet Weather Forecast Office requirements for improved:

- Aviation forecasts
- Specification of convective initiation and evolution
- Specification of precipitation type
- Prediction of precipitation amounts and area extent

Third, NASA has a Weather Research Roadmap, which is a combined vision of NASA, NOAA, and the research community. This Roadmap outlines recommended steps to help the nation achieve improvement in near-, mid-, and far-term forecasts using NASA's latest data and modeling research. The Roadmap sets weather forecast improvement goals, identifies key steps to achieve those goals, identifies enabling research for improved weather forecasts, and links this weather-program implementation plan to the NASA Science Directorate research strategy.

Fourth, DOT activities, including the FAA Aviation Weather Research Program (AWRP) are striving to increase scientific understanding of atmospheric conditions that cause dangerous weather impacting aviation. The research is aimed at producing weather observations, warnings, and forecasts that are more accurate and more accessible. Within the AWRP, FAA partners with NOAA, DoD, the National Center for Atmospheric Research, and the

Massachusetts Institute of Technology's Lincoln Laboratory to develop product development teams (PDTs). These PDTs are teams of scientists from the partner organizations who work together to solve aviation problems caused by weather. Teams are currently organized to address the following topics: in-flight icing, aviation forecasts, forecast quality, turbulence, winter weather, convective weather, terminal and national ceiling and visibility, model development and enhancement, advanced weather radar techniques, and oceanic weather. In addition, FHWA, NOAA, NASA and NCAR are working to improve surface data collection that improve weather information for surface transportation users and operators.

Fifth, through USWRP, Federal agencies are partnering with universities and other research institutions to mitigate the effects of weather disasters (such as hurricanes) and to improve predictions of precipitation and flooding. Four current USWRP initiatives promise immediate benefits to national security, energy, and the economy:

- The Weather Research and Forecasting model (WRF) will be used by both researchers and forecasters, putting research improvements into immediate operational use. With USWRP and other funding, a prototype has been developed and is currently being tested. WRF is a collaborative effort among a number of government agencies and universities.
- The Hemispheric Observing System Research and Predictability Experiment (THORPEX), a major international field experiment over the Pacific Ocean, will improve two- to ten-day forecasts for U.S. regions and urban areas. THORPEX is planned for 2003-2010, and involves dozens of institutions, and researchers and operational meteorologists from 14 nations from the Northern Hemisphere.

- Operational testbeds will evaluate new weather-prediction models and new forecasting techniques without interfering with the day-to-day operation of forecast centers. Two test beds are currently being developed—one for hurricane predictions and another for modeling improvements.
- Short-term forecasting improvements will focus on a few hours out to two days and will improve predictions of severe storms, distribution of precipitation, temperature, and air quality.

From an international to a local perspective, improving the accuracy, timeliness, and reliability of weather information is critically important. Gradually, more nations are recognizing the societal benefits to be gained through Earth observations and the efficiencies to be realized by working together. Within the U.S., an Integrated Earth Observation System (IEOS) will help realize those efficiencies, and create a synergy between improved weather forecasting and the development of an IEOS. Weather forecasters have made significant progress in establishing common requirements across the spectrum of users. Continued weather-forecasting improvements and a sustained weather-information infrastructure will depend on effective partnerships, implementing appropriate components of existing plans, and developing and implementing the IEOS. For a more in-depth look at the state of Earth observations in the Weather Forecasting area, as well as for a list of references, please see the Weather Forecasting Reference Document on the IWGEO website at http://iwgeo.ssc.nasa.gov.

Section 2: Reduce Loss Of Life And Property From Disasters

1. The State of Earth Observations for Disaster Mitigation

Disaster Mitigation Functional Requirements:

- Continuity of operations
- Continuous, real-time data streams
- Rapid tasking of other data sources
- Global coordination of resources
- Rapid generation of accurate information and forecasts, and
- Efficient sharing of information products, in formats that are adapted to users' needs.

Natural and technological disasters, such as hurricanes and other extreme weather events, earthquakes, volcanic eruptions, landslides and debris flows, wildland and urban-interface fires, floods, oil spills, and space-weather storms impose a significant burden on society. Within the U.S., disasters inflict many injuries and deaths, and cost the Nation $20 billion each year. The Earth observation systems needed to forecast and mitigate disasters are diverse in type and maturity. The Committee on Environment and Natural Resources (CENR) Subcommittee on Disaster Reduction report "Reducing Disaster Vulnerability through Science and Technology" identifies the many existing interagency and international partnerships that are involved in an array of valuable cooperative programs for improving the resiliency of American communities to all hazards. The Subcommittee for Disaster Recovery has identified many existing interagency partnerships that deal with particular hazards. An example is flood monitoring and response, which involves coordination among the NWS, USGS, FEMA and USACE. Another example is dealing with the hazards posed by volcanic ash clouds. Safe air traffic control involves coordination between NOAA (both the NWS and NESDIS), the USGS, the USAF, and the FAA.

Disasters can also span beyond our borders, where international cooperation is paramount to ensure public safety. Some key international partnerships and coordinating bodies for disaster observations include the WMO and the associated Meteorological Watch Offices, the nine Volcanic Ash Advisory Centers, the International Charter for Space and Major Disasters, the Preparatory Commission for the Comprehensive Nuclear Test Ban Organization, which has a number of monitoring systems, and the International Space Environment Service. We are beginning to see the success of linking global observations to help mitigate disasters, examples are the National Ice Center which collaborates internationally through the WMO/IOC; the International Ice Chart Working Group, formed in 1999, provides operational cooperation amongst national ice services, with regional (North American) collaboration handled by the US-Canadian Joint Ice Working Group. Another category of international partnerships includes programs such as the USGS Volcano Disaster Assistance Program (cosponsored by the USGS and USAID/OFDA) and the Civil Military Emergency Preparedness program of the USACE.

2. What Can We Observe Now?

Observation systems currently exist for use in observing wildland fires, earthquakes, volcanic activity landslides, floods, extreme weather, tropical cyclones, sea and lake ice, coastal hazards, pollution events and space weather.

Many of the data and observations are common to more than one hazard. For instance, there is extensive overlap among the weather or weather-driven hazards. Some overlap also exists among the solid-Earth hazards and, in certain areas, among floods, sea ice, and coastal hazards. However, there are other significant commonalities that may be less widely appreciated: wildland fires, volcano eruptions, and some pollution events have overlaps for thermal signals, gas emissions, smoke and aerosols, and sediment and other discharges into water. Seven of the individual hazards listed require information on soil moisture.

Significant overlap exists between the observational needs for pollution events, such as oil or chemical spills, and those for the natural events. In addition, most large natural disasters (especially wildland fires, earthquakes, and floods) result in significant pollution as part of the event.

Below is a brief summary of the observation capabilities that currently exist for each type of disaster:

> **Extreme Weather, Tropical Cyclones** See the section on Weather forecasting in this Appendix. These capabilities are augmented by 1) low-resolution topographic observations, and 2) location of infrastructure and transportation routes.
>
> **Flood hazards** The monitoring, evaluation, and forecasting of floods (such as those produced near large rivers, whether by large storms or spring snow melt) are relatively mature, and depend on a combination of ground-based and remotely-sensed data streams. Data categories include topographic observations, stream flow, groundwater levels, snow cover characterization, tides and coastal water levels, spatial distribution and density of manmade impervious surface area (ISA), and vegetation cover.
>
> **Earthquakes** Archiving of seismic records (by the USGS and IRIS) is systematic and more mature than for most other kinds of solid Earth hazard data. For example, the U.S. operates and maintains the Global Seismographic Network (GSN) of 137 stations spanning the globe for continuous monitoring of earthquakes and tsunami. Current observational capabilities other than seismic

monitoring include low-resolution topographic observations, high resolution gravity and electric field measurements, thermal and gas emissions, water chemistry, and ground water levels.

Volcanic eruptions Monitoring volcanic activity, including volcanic ash and aerosols, requires a wide range of ground-based, airborne and satellite support. Current observing capabilities include low-resolution topography, seismic monitoring, strain monitoring, monitoring of gas emissions, high resolution measurements of gravity and electric fields, physical properties of Earth materials, thermal emissions, water chemistry, and discharges into water.

Landslides Current capabilities include low-resolution topography, bedrock characterization, seismic monitoring, ground movement (including liquefaction), deformation monitoring, water levels, stream flow, and inundation areas.

Wildland and urban-interface fires These extremely complex events require rapid weather observations, at various time scales and spatial resolutions. Current observing capabilities besides needed weather observations and fire maps generated in response to an event, include vegetation condition and fuel loading, sediment discharges, stream flow, and low-resolution topography.

Coastal hazards, tsunami, and sea ice hazards These hazards require coordination of information across a range of observing systems. For example, accurate forecasting of storm surge and coastal flooding depends on combining hurricane landfall forecasts with stream flow information and tidal and wave height data. Available observations include low-resolution topography, characterization of surficial deposits, ground movement, seismic monitoring, physical properties of Earth materials, water chemistry, discharges into water, and stream flow.

Pollution hazards These hazards may be triggered by other hazard events (such as an earthquake or flood), or be induced by human activity. An example is the release of chemicals or petroleum on land, into fresh-water systems, coastal zones, the sea, or into the atmosphere. Oil spills can be tracked with satellite imagery, in particular with Synthetic Aperture Radar (SAR) imagery.

Other current capabilities include topography, smoke and ash cloud detection, water chemistry, stream flow, and inundation area.

3. What Can't We Observe Now?

Observation systems for disaster prediction and monitoring, though some are relatively mature, must be continually maintained and improved. There are still many significant gaps, including instrumental, temporal and spatial coverage, baseline data and models, communications networks, and decision-support tools. In addition, some existing capabilities are deteriorating or will be lost. Some major gaps include, but are not limited to:

» Easier access to Synthetic Aperture Radar (SAR) data. Currently this means seeking better access to Canadian and European C-band SAR satellite imagery. In addition, Japan plans to launch a new L-band SAR (the PALSAR sensor on the ALOS satellite) in 2006. That will be a welcome development, but PALSAR and other current SAR sensors are designed as research instruments, and share power and downlink capabilities with other sensors on the same satellites. Consequently, the amount of SAR data available is severely limited now, and will be for the next 6-8 years. Specifically, it is inadequate for both routine ice monitoring (the principal use of the Canadian Radarsat) and for routine use of interferometric SAR (InSAR) to monitor deformation caused by volcanic activity, or by local surface instability (such as landslides or subsidence) or by motions on faults or plate boundaries on a continental or global scale. Additional C-band (or X-band) and L-band SAR capability, to generate all-weather imagery suitable for InSAR, for a wide range of hazards, could address this gap.

» Improved access to moderate-to-high-resolution near- infrared (IR) and short-wave IR imagery is needed, especially for fire response, and for volcano monitoring. High-resolution imagery needs for volcanoes, plus rapid, tactical IR imagery support for wildfire response, would be better met by airborne IR cameras, as there will be less interference from clouds.

» High-resolution satellite and airborne imagery support are needed for nearly all types of disasters. For example, detailed images are needed for wildfire response not only during severe fire season, but also for pre-fire studies to characterize the health and types of vegetation, and fuel loading. Such information is essential to assess areas at highest risk of fire in the immediate future. Detailed mapping of geologic and topological features are essential for improved response to wildfires, solid Earth hazards, floods, ice hazards, and coastal hazards.

Examples of gaps in land-based observation capabilities include deformation monitoring for earthquakes, volcanoes, and coastal hazards; more extensive stream flow monitoring for extreme weather and flooding; improved seismic monitoring for earthquakes and volcanoes; detailed mapping of surficial deposits (including fill, dumps) for land-based hazards, ice hazards and pollution events; and strain and creep monitoring for earthquakes and landslides. Other problem areas include inundation forecasting, especially in heavily developed areas, sufficiently rapid modeling and warnings for flash flooding, and effective snow melt forecasting.

Other needs include the expansion of emergency airborne capabilities including UAVs (for severe weather, fire/fuels mapping, volcano observation, characterization of airborne contaminant plumes), and expansion of capabilities for airborne LIDAR and SAR (to support detailed observation of topography and topographic changes). Research into new instrumentation (cost-effective, portable, sensitive, accurate, and quickly deployable) to identify/monitor a wide range of trace gases, toxic chemicals, or explosives in soil, water, and the atmosphere would provide critically important data for many disaster and hazard situations. Remotely controllable sensors that can function in extreme or unusual environments (near erupting volcanoes, in wildfires, or in malfunctioning nuclear reactors) will be needed.

4. How are we Addressing Gaps?

Plans to address gaps include two new satellite systems—the NPOESS and GOES-R. These systems will replace current polar and geostationary satellites in 2009 and 2012, respectively. Both satellites will provide improved technologies to support the detection and monitoring of severe weather, tropical cyclones, volcanic eruptions and ash clouds, and will provide data essential to the fundamental research on these processes and events. Onboard instruments will have improved spatial and temporal resolution, and will include a wider range of spectral bands than instruments on current POES systems, although some bands currently available and used for fire detection will either be absent or too sensitive on the NPOESS equivalent for fire detection in daytime. In addition, the GEO Lightning Mapper will monitor lightning in support of better extreme-weather assessment.

Future weather-related solutions also include expansion of the commercial aircraft Meteorological Data Collecting and Reporting System (MDCRS) globally, and increased use of local carriers, expanded deployment of surface-based radar wind profilers to observe the atmospheric boundary layer, development and deployment of arrays of phased-array radars to significantly increase the quantity, quality and timeliness of weather information in extreme weather. In addition, operational deployment of long range, long endurance aerial vehicles will enable the persistent tracking and high resolution observation of atmospheric phenomena over their life cycle.

Most of the gaps in disaster-related Earth observations systems require further analysis and planning. Many land-based systems, such as stream flow monitoring and seismic monitoring, exist but need to be expanded and upgraded. Satellite observations of thermal emissions via infrared imagery, which could make a significant contribution to our ability to forecast and manage fires and volcanoes, must be expanded and improved.

For disaster-related Earth observations, the two overarching considerations for future Earth observation systems are:

(1) The development of a process whereby the unmet needs for expansion and modernization of the vast array of surface-based monitoring systems can be dealt with in the 10-year time span of the plan. This work is essential to maintain the benefits of the status quo, to define the needed communications infrastructure, and to prepare for the future expansion of population and infrastructure into areas of high risk. This deployment can be incremental, but it should be systematic, for all critical systems. This array of surface-based monitoring systems will provide the landscape-scale observations needed for basic research to understand natural hazards and their root processes, and to improve modeling and forecasting of hazard events.

(2) The clarification of responsibility for designing, building, launching and operating satellites that are intended to observe the solid surface of the Earth at moderate spatial resolution, with temporal resolution and spectral capabilities adequate for the range of natural hazards discussed here. NOAA/NESDIS covers weather and other atmospheric observational requirements, and many ocean requirements, but operational satellites for solid-Earth surface observations currently have no home. Earth surface observations are essential for both operational purposes and basic research on geographically distributed natural processes. For a more in-depth look at the state of Earth observations in the Reducing Loss of Life and Property from Disasters arena, as well as for a list of references, please see the

Reducing Loss of Life and Property From Disasters Reference Document on the IWGEO website at http://iwgeo.ssc.nasa.gov.

Section 3: Protect And Monitor Our Ocean Resource

1. The State of Earth Observations for Ocean Resources

Observing systems for ocean resources are in various stages of development and maturity. Some systems have been in place for over 100 years such as water level networks; others such as Autonomous Underwater Vehicles (AUVs) and ocean carbon monitors are relatively new. Observing system assets are available in various levels of operation and reliability. Research and pilot efforts are also in progress, either planned or transitioning from development efforts into the operational systems. New scientific knowledge has established the importance of monitoring the global blue water, in addition to our Exclusive Economic Zone (EEZ), inland seas, rivers and watersheds. Also critical is the concept of ecosystem management.

Monitoring Ocean Resource Functional Requirements:

- Open access to continuous, real-time, near real-time, and delayed data streams, and rapid access to archives
- Robust calibration and validation for all systems
- An efficient process to transition research into operations
- Global coordination of resources
- Rapid generation of accurate information and forecasts
- Efficient sharing of information products, in formats that are adapted to users' needs

The U.S. Commission on Ocean Policy Report and the U.S. Ocean Action Plan call for the integrated ocean/coastal observing system (IOOS) to be coordinated among Federal agencies, academics and regional ocean information groups. The National Oceanographic Partnership Program's (NOPP) National Research Leadership Council (NORLC) formed the Ocean.US Executive Committee (EXCOM) that oversees the activities of the Ocean.US office, which is now coordinating the development and implementation of the U.S. IOOS. Reducing the impacts to ocean resources will require better global datasets and improvements in now-casting, in addition to forecasting effects of weather, climate, and human activities on the coastal ocean, its ecosystems, and living resources. These drivers will require additional ocean observing capabilities, and extensive data management efforts, along with links to other ocean observing systems.

2. What Can We Observe Now?

Ocean observing systems can monitor many physical, biological, geological parameters using a variety of methods. As illustrative examples, remote-sensing methods can provide sea surface temperature, sea surface height, surface winds, ocean color, type and condition of coastal habitats; ship-based systems provide temperature and salinity profiles, fish abundance, age and condition, bottom topography; *in situ* systems provide river flows, water levels, sediment load, nutrient concentrations, biological community sampling.

Concerted national and international efforts have taken place for over a decade during the development of the Global Ocean Observing System (GOOS); where initial efforts focused on climate, and coastal systems implemented in several European countries. IOOS is the U.S. component of the larger Global Ocean Observing System (GOOS) that is being developed under the auspices of IOC/UNESCO, both of which will be vital components of the Global Earth Observation System of Systems (GEOSS).

Many of the data and observations are common to more than one ocean resource issues. For instance, water levels are needed for navigation safety, flood forecasting, habitat restoration and coastal zone management. On the other hand, fish abundance has more limited application. Specific sensor types and networks used include:

- Remote-sensing instruments on aircraft, satellite and land-based platforms, such as: passive electro-optical imaging sensors (multispectral and hyperspectral) and active electro-optical (LIDAR); passive microwave (radiometers and sounders) and active microwave (altimeters, scatterometers, and Synthetic Aperture Radar), and high frequency radar.
- Ship-based measurements, such as net sampling, manual and pumped measurements of physical, chemical, optical and biological properties, and acoustic measurements of bathymetry and currents.
- Coastal, open ocean, or land-based *in-situ* systems that allow for unattended (autonomous or semi-autonomous) operation, such as: wind, wave and temperature sensors on moored buoys; drifters; shore based platforms such as tide gauges; water quality sensors; and autonomous underwater vehicles (AUVs).
- In-water measurements that require attended operation, such as: manual sampling of underwater species; remotely operated vehicles (ROVs); underwater video/photography; and underwater laboratories.
- Sentinel and research sites located at the shoreline; in bays, estuaries, rivers, offshore, and the deep ocean; and on the ocean floor.
- Systematic regional fisheries and protected species surveys conducted by observers on ships and aircraft to establish seasonal indices of abundance and distribution, and, from these, key indicator species over time.
- Long-term sampling programs that measure contaminants in the water column, sediments and marine organisms, such as NOAA's National Status and Trends Program; EPA's National Estuary Program; and EPA's National Coastal Assessment Program.

Orbital sensors are available on satellite missions, such as NOAA's Polar-orbiting Operational Environmental Satellites and Geostationary Operational

Environmental Satellites; DOD's Defense Meteorological Satellite Program, NASA's Landsat, SeaWiFS, Terra, Aqua, TRMM, TOPEX/Poseidon and Jason-1 satellites; and various commercial ventures. Examples of global *in-situ* systems include the Argo buoys, and the U.S. contribution of drifting buoys. Global systems that combine *in-situ* and satellite assets include NOAA's contribution to Global Sea Level Observing System (GLOSS) and the U.S. Climate Observation Program. National *in-situ* systems include NOAA's National Data Buoy Center (NDBC) networks of weather buoys and land-based measurement stations, National Water Level Observation Network (NWLON), Physical Operational Real-Time System (PORTS), and NOAA's Ecosystem Observation System (NEOS); EPA's National Coastal Assessment Program and National Estuary Program; and the USGS stream gauge network.

3. What Can't We Observe Now?

Observation systems for ocean resources must be continually maintained and improved. There are still many significant gaps, whether in instrumentation, temporal and spatial coverage, baseline data and models, communications networks, and decision-support tools. These have been identified in IOOS and Global Ocean Observing System reports and are provided in detail in the GEO Technical Report. Key areas for observational capacity building are deploying enhanced sensor packages that are more precise and accurate, are automated, and require less maintenance. Target areas for improvement are biogeochemical measurements, remotely-sensed technologies including remotely-operated vehicles, small automated free flyers, and/or modeling to increase the observational network capacity. Other major gaps include:

Remote-sensing measurements:

- Better procedures for calibrating and representing data in coastal waters
- Precise sea surface height and surface vector wind measurements
- Finer scale resolution sensors for sea surface temperature, salinity, winds, ocean color
- Continuity in ocean color, winds and sea surface height measurements
- Better systems to determine quantity and quality of coastal habitats (intertidal, seagrasses, kelp beds, water column, sediments)
- Need to acquire ocean color imagery (multi- and hyperspectral) of coastal areas at sufficient frequency and optical resolution to identify and analyze changes in the spatial distribution and extent of coastal and near-shore habitats
- Integration of *in-situ* measurements with remotely-sensed observations

Ship-based measurements:

- More ship-based measurements of temperature and salinity profiles (need to equip more ships of opportunity)
- Better determination of global fluxes of heat, fresh water and carbon (need to repeat measurements similar to those from the World Ocean Circulation Experiment)
- Comprehensive and standardized fisheries and protected species surveys, measuring relative abundance from fishery-independent data to improve the quality of LMR stock assessments and the understanding of population dynamics
- Better instrumentation for physical, chemical, geological and biological information
- Multi-beam sonar measurements to collect detailed bathymetry and habitat information, particularly in near-shore and shelf environments, but also in watersheds and out to the EEZ

In-situ measurements:

- Long-term, continuous measurements of river flow volume at more sites
- More sites for water level measurements
- More frequent sampling of key properties, such as sediment load, nutrient concentration and selected chemical contaminants, at more sites
- Better systems to determine quantity and quality of coastal habitats (intertidal, seagrasses, kelp beds, water column, sediments)
- Expanded coastal network of moored and fixed-platform instruments at more locations that measure meteorological variables (including atmospheric deposition) and oceanographic properties (physical, chemical, biological)
- Additional deep ocean observatories and sentinel sites
- New remote-sensing/AUV technologies/techniques to obtain fishery-dependent and fishery-independent data
- Innovative and cost effective techniques to eliminate the need for manual sampling, photography, etc.
- Standardization of methodologies for biological community sampling

4. How are we Addressing Gaps?

Currently, evolutionary changes of *in-situ* measurements of key ocean variables are expected, with corresponding changes in data communication and local initial data processing (QA/QC checks for example). More accurate and comprehensive remote-sensing of key variables in coastal regions is expected in the next generation of U.S. satellites (GOES-R, NPOESS), aircraft, ships and AUVs.

National and international partnerships involving ocean resource data will be key to addressing ocean observation gaps. U.S. Federal agencies and the

U.S. ocean research community have played lead roles in development of the IOOS and GOOS, global and basin scale satellite systems and the development and implementation of international research programs of global scope, including WOCE, JGOFS, TOGA, CLIVAR, SOLAS, CEOS, and IMBER. These efforts do much to lay the foundations for the partnering required to achieve the necessary coverage of the global ocean and of coastal waters regions. These ties will need to be continued and strengthened. Strengthening and formalization of critical international partnerships is also needed, so that global coverage and open access to all nations' ocean data are assured.

Because there are many gaps and limited resources, comprehensive analysis and planning is needed to determine the location and attributes of existing and planned observing systems, and where to fill gaps for the greatest benefit. In the interim, maintaining existing systems and integrating data that are currently available into standardized formats, will provide users rapid and easy data access. Developing new products that combine available data sets are also high priority actions to consider. For a more in-depth look at the state of Earth observations in the Protecting and Monitoring Ocean Resources area, as well as for a list of references, please see the Protecting and Monitoring Ocean Resources Reference Document on the IWGEO website at http://iwgeo.ssc.nasa.gov.

Section 4: Understand, Assess, Predict, Mitigate, And Adapt To Climate Variability And Change

1. The State of Earth Observations for Climate

Several new Earth observing satellites, suborbital systems, surface networks, reference sites, and process studies are now producing unprecedented high-quality data that have led to major new insights about the Earth-climate system. The United States is now contributing to the development and operation of several global observing systems which collectively attempt to combine the data streams from both research and operational observing platforms to provide for a comprehensive measure of climate system variability and climate change processes. These systems provide a baseline Earth observing system and include: Earth observing satellites; the global component of the Integrated Ocean Observing System; the Global Climate Observing System (GCOS) sponsored by the World Meteorological Organization; the Global Ocean Observing System sponsored by the Intergovernmental Oceanographic Commission; and the Global Terrestrial Observing System sponsored by the Food and Agriculture Organization. Coordination of Federal acquisition of climate information, and support for its application, is a required ongoing activity of Federal agencies that participate in the Climate Change Science Program (CCSP) and the Climate Change Technology Program (CCTP), under the Committee on Environment and Natural Resources (CENR) of the National Science and Technology Council (NSTC).

Earth observations are urgently needed by Earth system models. Earth observation models are scientists' primary tools for: (1) integration of observations into a comprehensive analysis of the climate system; (2)

forecasting of the climate system on multiple time/space scales; and (3) simulation of the impact of a particular gap or enhancement of GEOSS. Existing Earth system models (for example, from GFDL, NSIPP, GMAO, NCAR, NCEP, and those of our international partners) are now transitioning to an improved architecture, the Earth System Modeling Framework (see http://www.esmf.ucar.edu/), that will enable improved incorporation of new observations, comparison of multiple models, and testing and validation of new approaches to climate modeling.

Climatic Functional Requirements:

- Improved knowledge of Earth's past and present climate, including natural variability, and understanding of causes of observed variability and change
- Climate system variables that specify the state, forcings, and feedbacks
- Reduced uncertainty in Earth's climate change forecasts
- Integrated observations from operational and research observing systems
- Better understanding of the sensitivity and adaptability of natural and managed ecosystems

Required observed variables include benchmark large-scale climate observations such as the total radiative energy output from the Sun that drives the Earth's climate system, the Earth's global average surface temperature, the atmospheric concentration of CO_2 and other atmospheric constituents, as well as climate variables such as precipitation, land use, and land cover, that undergo regional and local changes that have significant environmental and human impacts. In order to meet climate requirements, monitoring systems for climate must adhere to the 10 GCOS climate monitoring principles listed in the CCSP Strategic Plan. For satellite systems, CCSP specifies an additional 10 principles to ensure that observations meet the required stringent standards of calibration and sampling necessary for useful climate applications.

Another critical challenge is to maintain current observing capabilities that already exist in each of these areas. For example, maintenance of the observational record of stratospheric ozone is essential so that the effects of climate change on the nature and timing of expected ozone recovery can be discerned. Other key variables requiring maintenance include radiative energy fluxes of the Sun and Earth, atmospheric carbon dioxide, and global surface temperature. Since the value of existing climate datasets greatly increases as the record is extended in time, it is imperative that existing observing capabilities be maintained and improved, while at the same time new requirements are incorporated.

2. What Can We Observe Now?

A system that integrates atmospheric, oceanographic, terrestrial, cryospheric and cross-cutting observations does not currently exist, per se. However, many components are available. For example, GCOS is a fairly well documented but not completely implemented international approach that has a process to identify climate requirements. GCOS is intended to provide a focused set of observations from a subset of established measurement sites that are considered to have sufficient climate history and spatial distribution. The system discussed here, however, goes beyond GCOS. The CCSP has expanded the initial inventory of important climate observations to encompass the needs of research and applications related to the global cycles of carbon, water, energy, and biogeochemical constituents; atmospheric composition; and changes in land use.

A current inventory of U.S. systems contributing to global climate observing, and related to the atmospheric, oceanic, and terrestrial climate subsystems, can be found in the U.S. Detailed National Report on Systematic Observations for Climate.

3. What Can't We Observe Now?

The GCOS list of essential climate variables can be found in the GCOS Second Adequacy Report, April 2003. This set of required observables provides an excellent baseline, but will clearly need to be augmented. For example, incoming solar irradiance is listed, but also needed are *in-situ* measurements of profiles of radiative fluxes in the atmosphere. Additional extensions are needed for atmosphere, ocean and terrestrial variables. A process for updating these variables needs to be established as we learn more about the Earth's climatic system.

4. How are we Addressing Gaps?

GCOS, in consultation with its partners, is developing an implementation plan, if fully implemented, will provide most of the observations of essential climate variables detailed in the GCOS Second Adequacy Report. As the U.S. plan for climate observations moves forward, it should strive to build on the GCOS Implementation plan (*Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC,* GCOS-92, WMO/TD 1219, 136pp.) by addressing the following elements over the near-term (2-4 years), mid-term (4-7 years), and long-term (7-10 years).

> **Maintenance and Standards** A high priority is to maintain and extend the records of key climate variables such as global carbon dioxide, ozone, temperature, and other essential climate variables now being monitored by current systems. The

climate quality of these records must be assured by adherence to the GCOS climate monitoring principles, as extended by the CCSP Strategic Plan to cover satellite systems.

Modeling and Integration Continued development and improvement in climate analyses and periodic reanalysis is required for integration of climate observations. Continued development of ensemble forecasting for climate is needed for applying and evaluating observations, and for better definition of requirements for future observations.

A detailed phase-in plan will be needed to provide efficient integrated implementation, to address all climate change challenge themes within realistic budget constraints, and to take advantage where possible of governmental and non-governmental partnerships.

Near-term (2-4 years):

Land/Ecosystems/Human Dimensions Improve monitoring, measuring, and mapping of land use and land cover, and the management of these data; determine cycling of nutrients such as nitrogen and how these nutrients interact with the carbon cycle; move forward on plans to transition Landsat-type data collection to an operational platform.

Polar/Feedback Enhance capacity to observe land and sea ice parameters including ice thickness; develop continuous high-resolution altimetry over the ice sheets, and SAR capability to monitor glacial advance/decline; improve resolution of global gravity measurements; integrate modeling of global climate and glaciers/ice sheets.

Aerosol Reduce uncertainties in the changing aerosol radiative forcing of climate. This requires reduced uncertainty in the sources and sinks of aerosols and their precursors, in aerosol solar absorption, and in aerosol effects on cloud radiative fluxes and precipitation. Direct observations of aerosol physical and chemical properties and their interaction with clouds and precipitation are urgently needed to estimate the aerosol forcing directly from observations and to improve model treatments of aerosol forcing.

Water Planned satellite measurements and focused field studies to better characterize water vapor in the climate-critical area of the tropical tropopause (the boundary between the troposphere and the stratosphere)

Carbon Determine North American and oceanic carbon sources and sinks; the impact of land-use change and resource management practices on carbon sources and sinks; secure the measurements needed for the North American Carbon Program; enhance the ocean carbon observing network.

Mid-Term (4-7 years):

Water Improve accuracy and global diurnal sampling of precipitation and water vapor to identify trends in the frequency, intensity, and duration of the water cycle; improved global/regional ocean and terrestrial observing systems and data exchange; improved technology (satellites and *in situ,* including suborbital, surface, and sub-surface) to measure soil moisture and evapotranspiration; improved observations and modeling of water vapor-cloud-climate-radiation feedback processes; closure of terrestrial hydrological budgets; impacts of climate change on the global/regional water cycle; and studies related to physical, biological, and socioeconomic processes to facilitate efficient water resources management.

Radiation Budget Provide for continuity of solar and Earth-emitted radiation budget observations at the top-of-atmosphere and surface, to continue the satellite record that began with Nimbus-7 in 1978, continues with current Earth Observing System platforms, and is planned to be extended by NPOESS satellite missions beginning after 2010. Equally important is to maintain the related network of surface stations such as the Baseline Surface Radiation and Atmospheric Radiation Measurement sites, and the USDA UVB Monitoring and Research Network. In addition, improve the accuracy and stability of current radiometers and better characterize the existing historical record of radiation budget measurements.

Long-term (7-10 years):

Temperature Reducing uncertainties in the evaluation of temperature trends will require: (1) implementing an improved climate monitoring system designed to ensure the continuity and quality of critically needed measurements of temperature, and concentrations of aerosols and trace gases: and (2) making raw and processed atmospheric measurements accessible in a form that enables a number of different groups to replicate and experiment with the processing of the more widely disseminated data sets such as the Microwave Sounder Unit (MSU) tropospheric temperature record. Multiple independent atmospheric sounding systems (for example,, microwave, infrared, and GPS occultation) will produce atmospheric temperature and water vapor fields that are more accurate and reliable than any one sounding system by itself.

Paleoclimate Enhance and where possible regularly update paleoclimate observations and data management systems to generate a comprehensive set of variables needed for climate change research; enhance tree ring, coral and ocean core records. Gaps in paleoclimate observations can be better addressed by enhancements in: (1) 500-2000 year long coral records to reproduce temperature and salinity in the tropical oceans; (2) high sedimentation rate deep sea cores; and (3) marine geochemical proxy records of temperature trends for the past 2,000 years using corals, mollusks, and marine sediments from around the globe.

An area requiring future development is the ability to not only track climate anomalies but also to attribute them on multiple time scales to: (1) external forcings (solar, volcanoes, atmospheric composition); (2) internal forcings (for example, El Niño Southern Oscillation, Sea Surface Temperatures and ocean heat content, soil moisture anomalies, state of vegetation, and sea ice); and (3) natural variability (essentially unpredictable).

Analysis and planning is envisioned as a major part of these activities, so as to maintain and advance existing systems and address gaps in observations. Creation of new systems will involve the requirements of users, and the need for access to data and results in a timely fashion. The development of decision support tools will help the diverse user community understand results. A feedback loop between users and system developers will further optimize observations and the utility of support tools.

Climate observations need to be taken in ways that satisfy the climate monitoring principles and ensure long-term continuity and ability to discern small but persistent signals. The health of the monitoring system must be tracked and resources identified to fix problems. Satellite observations must be calibrated and validated, with orbital decay and drift effects fully dealt with, and adequate overlap to ensure continuity. Reanalysis of the records must be institutionalized along with continual assessment of impacts of new observing and analysis systems. Such an end-to-end Earth information system will be key to the success of the U.S. effort in supporting the GEOSS over the next 10 years. For a more in-depth look at the state of Earth observations in the Climatic Variability area, as well as for a list of references, please see the Climatic Variability Reference Document on the IWGEO website at http://iwgeo.ssc.nasa.gov.

Section 5: Support Sustainable Agriculture And Forestry, And Combat Land Degradation

1. The State of Earth Observations for Sustainable Agriculture and Forestry, and Combating Land Degradation

The state of agriculture and forestry observations continues to mature, as technology provides us with more tools to monitor ground cover. Partnerships exist between private land managers, Federal agencies, Conservation

Sustainable Agriculture and Forestry, and Combating Land Degradation Functional Requirements:

- Land Cover Assessment
- Change Detection
- Soil Moisture Content
- Species Composition Surveys
- Linking Observations Across Different Scales

Districts, Resource Conservation and Development Councils, state and local conservations agencies and organizations, non-governmental organizations, state, local and tribal governments, rural communities, businesses, universities and others. Cooperation among these organizations is increasing agricultural productivity and efficiency, conserving natural resources, improving the environment, and enhancing quality of life for rural areas.

However, we are realizing the weaknesses of Earth observations from non-integrated, stand-alone observations. Creating useful information out of disparate databases is extremely time consuming, and is therefore often ignored. Inferences based upon one source of data can prove misleading to decision makers. Integrating various key measurements of the ecosystem will provide a truer perception of the actual environment, leading to better decisions on how to manage our scare resources.

2. What Can We Observe Now?

Observation systems for monitoring agriculture, forestry and land cover exist on a variety of scales. Some of the observations currently being used include:

- Land cover and land use within, and surrounding, a particular landscape or ecosystem: the required detail for meeting program objectives ranges from highly specific (crop type, species, plant community, etc.) to general (agricultural, forested, urban, etc.). Definitions of land cover vary by application and by spatial resolution, as do requirements for accuracy. Imagery ranging from panchromatic aerial photography to coarse resolution multispectral satellite data are used for land cover and land use analysis.
- Change in land cover, and plant, and animal species composition: it is important to assess short term changes, such as within a growing season, and long term ranging, from years to decades or more.
- Field data in the form of animal specimen locality records and vegetation plots are used for modeling habitat distribution, and calibrating remotely-sensed spatial data, as well as for validation and accuracy assessment. Field data for operational purposes are frequently the most expensive to acquire.
- Topography in the form of a digital elevation map (DEM): This is commonly used as an element of base maps. Accuracy requirements range from sub-meter to tens of meters. Photogrammetric methods still dominate acquisition. RADAR, LIDAR and kinematic GPS are increasingly used and may replace photogrammetric methods. Watershed boundaries are especially important to producers, land managers, and governmental programs focused on soil and water quality issues.
- Soil series maps and USGS 1:24,000 scale maps depicting waterways, and cultural features, etc. are common sources of base maps for many applications. Use extends beyond suitability for planting to susceptibility to erosion, construction of infrastructure including access routes, etc.
- Long-term data for change detection, calibration of algorithms, and species inventory: There is a need to continue converting historical imagery, maps, field notes, and data sheets to digital form.
- Development of infrastructure for land use planning: Highways, pipelines, and train routes require detailed surveys for optimal placement to minimize land degradation while maximizing efficient transportation.

A tool commonly used is the Geographic Information System (GIS). GIS is employed as a tool during data collection, as a common platform for assimilating data from multiple sources, conducting analysis, and communicating information. Data and information are communicated via tables (statistics) and maps. Digital maps from a GIS can be used to drive variable-rate within-field planting, irrigation, and agrochemical applications.

Land observation needs range from sub-landscape to global. The time scales range from hourly to decades. Applications now demand more accurate and finer scale information as the intensity of land use increases and expands into less resilient soils, and less favorable climatic conditions. Industry needs are primarily for higher spatial and temporal resolution. Higher spatial resolution is also particularly important for many international users. Small cultivation areas and different cultivation practices of many regions of the world often make it difficult to ascertain what parts of a landscape are under cultivation by developing countries.

3. What Can't We Observe Now?

A few of the omissions in the realm of land observations are either because a sensor has not been developed, or because deployment of a particular sensor is limited. This limitation could be due to cost, data archiving problems, or socio/political reasons. Here is a list of a few omissions we currently have in the land observation realm:

- A general lack of appropriate spectral resolution measurements by both *in situ* and remote-sensing devices. For example, hyperspectral measurements increase the observed parameters of a given subject from less than 20 bands to over 100 bands. Each band can then be a useful criterion to help discriminate individual objects, be it vegetation, soil types or man-made surfaces.
- Lack of sufficient *in-situ* sensors spatially and temporally. Currently there are large gaps in both physical area and in frequency of measurement for many essential parameters. Examples are soil moisture, precipitation, and air quality. Our current systems attempt to mitigate these losses using techniques such as kriging (a geostatistical approach to modeling), but extrapolations of conditions based on a few readings is not as accurate as many *in situ* measurements
- There is a need to move some of the current sensor systems in use today from a research status to an operational status. This is necessary to ensure continuity of experimental observations that have been proven to provide critically important information. Some of the sensors used today are actually research sensors, with no identified follow-on system or even maintenance of the existing system.
- Weather and climate-related observations, such as incoming solar radiation and CO_2 flux, used in models ranging from local to global in scope, are spatially sparse. The measurements are becoming increasingly important globally, and the demand for better modeling means more observations.
- Computer modeling of various Earth processes continues to be refined. Validation of these complex models will need sensors with increasing resolution and density to substantiate or refute current theories.
- Site-specific observations are often required due to the complexities of certain ecosystems. Optimization and validation of models for these specific locations is critical. Interdisciplinary teams will be required to develop the technologies for efficient and reliable assessments of these areas.

- Data distribution will be one of the most challenging tasks to overcome. As the increased sensor capacities increase the volume of data collected, it will be even harder to obtain data in a quick and reliable way. How to protect and insure the integrity of the data over time is also a huge challenge.
- Development of convenient and accurate decision support systems that autonomously collate this raw data and process it into useful information is another gap that needs to be closed. Only then can we truly understand what the data are telling us.

4. How are we Addressing Gaps?

Currently our existing baseline observations systems are being enhanced in resolution and in spectral discrimination, mainly due to technology advances. This is true for our operational systems, such as the GOES weather satellites. There have been other satellite missions recently launched, such as NASA's Terra Program which are able to perform such functions as surface temperature readings day and night, vegetation indices corrected for atmosphere, soil, and directional effects, and aerosol properties defined as optical thickness, particle size, and mass loading. There is increased recognition of the value of automated *in situ* systems for observing the processes and state of land, water, and air resources. As the sophistication and reliability of systems such as micrometeorological stations, soil moisture and temperature sensors, and sunphotometers increase, the costs have come down. This provides greater opportunities to increase spatial and temporal coverage.

Mechanisms for data delivery of observations from systems to users will be the extremely challenging. Questions as to the long-term storage of data, who has responsibility for data recovery, and how reliable feedback loops for data quality all must be answered. For a more in-depth look at the state of Earth observations in the Sustainable Agriculture and Forestry, and Combating Land Degradation area, as well as for a list of references, please see the Sustainable Agriculture and Forestry, and Combating Land Degradation Reference Document on the IWGEO website at http://iwgeo.ssc.nasa.gov.

Section 6: Understand The Effect Of Environmental Factors On Human Health And Well-being

1. The State of Earth Observations for Human Health and Well-Being

Observations providing information for human health and well-being are essential for human life, economic growth to support life, and to foster methods to assure the vitality of ecosystems that support life. From a social and economic perspective, observations to generate information for human uses, such as sustainable development, industry, agriculture, water quality and waste disposal, air quality, and the protection of human and ecosystem health, are critical. With continued growth in human population and associated resource use, the need for enhanced observations, information, tools and models, and decision support systems to inform decision-makers and the public is paramount.

The Human Health and Well-Being discipline is on the cusp of having a number of opportunities coming into place to advance this societal benefit. The future is bright and a number of opportunities are suggested below and in the associated technical reference document. Examples of these opportunities include the air quality field, where AirNow/AQI predictions are carried in daily papers. In addition, opportunities are emerging to deal with such air and water quality issues as asthma, water quality for recreational swimming and harmful algal blooms.

Human Health and Well-Being Functional Requirements:

- Increased coverage and resolution of observations
- Observations of environmental elements not presently observed
- Issue-specific observations, especially those related to air and water quality
- Long-term, sustained observations of ground cover, and air and water quality

Monitoring of the global availability, use, and cost of resources, as well as their influences on human health and the environment, is an important requirement for developing sound decisions. Observation and analysis of consumption and supply through the integration of technologies and sustainable design techniques is increasingly important for managing resources and decision-making that influences human health and well-being.

These parameters of interest vary geographically, making local and regional monitoring critical. Future growth of the world's economies will depend on sustained, secure, and reasonably priced resources, as well as accurate forecasts of needs. Improved forecasting can help reduce costs of many activities. For example, it is known that the use of improved weather forecasting accuracy is critical for food production and its timely, safe and cost effective transport to people.

The beneficiaries of improved monitoring, information, and decision support systems will be society as a whole. However, in order to assess the efficacy of existing systems, and identify gaps and future needs, we first must understand who the critical users are, and identify their needs.

The observing systems, data systems, associated tools, and the community of users of the information will constitute the components of an Earth information system, which is the end goal of the GEOSS. The observing systems must be linked to an integrated data system that provides full and open access, which in turn links to tools that support the generation and access to information needed by the health community including researchers, service providers, and policy makers.

Users of data and information include government agencies, industry, universities, public institutions, non-governmental organizations, and the public. Applications include research and operations, policy for adaptation and mitigation, as well as decision making by businesses, organizations, and individuals, applied in local, regional, national, and international contexts. Coordination of Federal acquisition of information and support for applications is an ongoing activity.

2. What Can We Observe Now?

Several new Earth observing satellites, airborne or suborbital systems, *in-situ* or surface networks, reference sites, and process studies are now producing unprecedented high quality data that have or will lead to new insights about human health and well-being.

A number of groups collectively attempt to combine the data streams from both research and operational observing levels or platforms to provide for a comprehensive measure of variability and change processes. These systems provide baseline Earth observations and they include NIH, EPA, CDC, NASA, NOAA, USGS, USDA, and others employing ground level, airborne or mobile level, and Earth observing satellites in a variety of system-integrated programs or activities.

A critical challenge is to maintain and operate current observing capabilities that already exist. For example, maintenance of observational records at all levels is essential so that the effects of change in, say, air quality and drinking water quality can be discerned. Other key variables requiring maintenance include, for example, measures of disease, population characteristics, food production and distribution. Since the value of existing datasets greatly increases as the record is extended in time, it is imperative that existing capabilities be maintained and improved, while at the same time new requirements are incorporated.

Due to the multiple factors involved, scientists from different disciplines have been or may be called upon to work together. To create an integrated observation system for both environmental and health research, management, and decision-making communities, partnerships are essential. Strong partnerships help ensure that the appropriate data sets are collected, integrated, interpreted, and used properly. It will be critical to develop a system of collaborative partnerships among agencies, state and regional governments, tribal nations, and the public to create a useable system. Additionally, Federal agencies and partners must encourage consistent practices, interoperability, and information sharing among state and local agencies that gather data. Examples of existing partnerships include: NOAA/NWS provides weather forecasts to CDC staff who are involved in research on the effects of heat waves and in working with State and Local officials to prevent heat-related morbidity and mortality. Similarly, HHS and FEMA for their disaster preparedness and response roles rely on NOAA/NWS to predict the location and severity of extreme weather events. NIAID and NASA have an interagency agreement to support training for African scientists in the use of new technologies for the control of malaria, to determine if remotely-sensed information could be used to develop predictive models for risk of malaria transmission.

Bacterial contamination is monitored by local public health agencies. NOAA, EPA and other Federal agencies assist by providing updated methodologies. National databases on bacterial contamination are updated by collecting data from state agencies that, in turn, collect it from the local agencies that made the measurements. The USGS National Biological Information Infrastructure (NBII), which is composed of multiple sector partnerships (Federal, state, and local agencies; universities; private industries, and non-governmental organizations), provides increased access to biological data and information on our nation's plants, animals, and ecosystems to a variety of audiences including researchers, natural resource and health managers, decision-makers, and the public.

Environmental monitoring that crosses national borders is often best coordinated by the appropriate organizations. For example, the international aspects of bacterial water quality monitoring are best handled through the World Health Organization or, in the Americas, through the Pan American Health Organization. New partners from the remote-sensing and environmental community could provide useful contributions to those monitoring activities.

Application of enhanced *in-situ* and remote-sensing data and techniques to air quality evaluations is very promising, and a potential area for early, demonstrable results. Efforts like the State of New York GRID air quality forecasting system, a joint effort between the State, EPA and NOAA, should be encouraged to demonstrate the promise of forecasting conditions for the public and decision-makers, but also track the results to see if forecasting produces improved air quality by people and governments making decisions that reduce pollution.

3. What Can't We Observe Now?

It is necessary to enable the easy transfer of environmental information to researchers, response communities, and decision makers. Thus, it is important to develop user-friendly systems for quick access to Earth science data for applications in human health and well-being. However, many factors have hindered the use of space- and ground-based data for health applications. Some of the most important are:

- Lack of appropriate spatial, temporal and spectral resolution measurements by the current ground or *in-situ* and satellite sensors.
- Lack of good communication and understanding between the data producer community and users in the health and environment fields of research.
- Absence of continuous temporal and spatial data sets required for the study of specific diseases or disorders, including human activity patterns.
- Access difficulties to data and value-added products due to differences in format, resolution, projection, computer systems and lack of an integrated system with generally accepted standards for unified studies.
- Insufficient technology transfer methods to move from research to operational environments, and need for an information system, enterprise architecture, and/or systems of web portals.
- Inadequate development of remote-sensing and ground-based methods to continuously monitor speciated environmental pollutants or their indicators affecting human health.
- Lack of ongoing observation systems available for collecting human activity or human exposure data.

- Lack of very high spatial resolution sensors for monitoring mosquito-breeding sites.

4. How are we Addressing Gaps?

Focused efforts are needed to improve technology transfer and development of user-friendly tools, indicators, models and decision support systems for mass distribution. Effective implementation requires promotion of both public and private sector use and dissemination of observation data/products; as well as effective technology transfer to extend the combined use of ground or surface measures, remote-sensing, and models and decision support systems for the needs of decision-makers and the public. This, in turn, requires the development of information systems and/or enterprise architectures and systems of web portals, all to communicate more efficiently observations, information, indicators, models and decision support systems.

In particular, the combination of *in-situ* measures and remote-sensing data along with GIS, GPS, models, indicators and others are fundamental tools. These tools can facilitate the planning, analysis, surveillance and intervention in the control and management of infectious diseases outbreaks, air and water quality decisions, food security and transportation, and the like. To take full advantage of these technologies, it is necessary to be fully integrated to benefit the decision-maker and public in timely and cost-effective ways.

Many infectious diseases are greatly impacted by the weather and by patterns of agriculture. Qualitative and quantitative analysis of agriculture and vegetation cover remains a key need. Improved resolution will assist to identify, understand, and predict crop yields and evaluate the scale of potential problems in the food supply and its transportation, such as crop failure and famine or unexpectedly high yields that may presage a booming rodent or insect population and associated disease risks.

It is important to note that most research linking environmental exposure to the increased prevalence or exacerbation of asthma and allergy is based on *in-situ* measurements in the local environment. The further integration of remote observations, models and decision support systems will lead to a better understanding of causative conditions and related decision-making. Other needs which are being addressed include:

- » Adequate data archival capabilities to allow for a better understanding of the development of chronic diseases and diseases resulting from long-term environmental exposures.
- » More extensive databases on human activities to integrate with pollutant concentrations to estimate exposures, and particularly so for air and water quality.
- » Integration and display of data from multiple scientific disciplines in a meaningful way in order to create a successful integrated observation system that is useable by members of the environment; human, animal, and plant health communities; and by decision makers.
- » Appropriate spatial and temporal resolution data to relate directly to exposure or human health.
- » Archive model outputs for use in future health and epidemiological studies to determine relationships between environmental exposures and disease.
- » Continued research on use of genomics in monitoring for environmental factors that influence human health and well-being

Current *in-situ* and remote-sensing technologies offer great potential for human health studies. It is important to maintain and enhance existing systems. The advent of geostationary sensor systems with improved spatial and spectral resolution would allow study of air, weather, wetland, water and related phenomena. Maintenance and enhanced day/night sensing capability is important in the UV, visible, near, middle and far infrared, as well as the microwave regions. A denser network of air and water quality observations would also improve analysis of human health issues.

The U.S. should also increase capacity for developing country scientists through training programs and collaborative research programs. Examples of existing programs include the Fogarty International Center at NIH/HHS International Research Training in Environmental and Occupational Health Program and its Health, Environment and Economic Development Program now operating in 11 countries. NASA, NOAA, EPA (STAR grants and fellowships), and other Federal agencies also have programs for capacity building in related areas.

For a more in-depth look at the state of Earth observations in the Human Health and Well-Being area, as well as for a list of references, please see the Human Health and Well-Being Reference Document on the IWGEO website at http://iwgeo.ssc.nasa.gov.

Section 7: Develop The Capacity To Make Ecological Forecasts

1. The State of Earth Observations for Ecosystems and Ecological Forecasting

The state of Earth observations for application to ecosystems and ecological forecasting are less mature than for many of the other societal benefits. While a number of activities exist, which are based on years of international and national collaboration, many more needs are awaiting to be addressed. It is now widely recognized that ecosystem forecasting is critical to reducing environmental threats, maintaining a healthy economy, and to sustaining a wide range of ecological services upon which society depends.

Ecosystems and Ecological Forecasting Functional Requirements:

- Understand ecosystem composition, structure, and function
- Monitor status and trends in ecosystem conditions and important ecological processes
- Develop and improve ecological prediction and interpretation tools
- Develop and test a comprehensive forecasting framework through pilot and case studies
- Efficient sharing of information products, in formats that are adapted to users' needs

Forecasting species and environmental changes represent a formidable challenge, in that the basic mathematics and modeling approaches for such forecasting are still in their infancy. Ecosystem complexity and scaling issues increase error and uncertainty in forecasting. Ecological forecasting requires the acquisition of a wide range of environmental data, depending upon the scale (from micro to macro) of the initiative. Most systems will also require extensive tools to be developed, or at the very least, enhancements to existing models.

2. What Can We Observe Now?

Ecological forecasting is an integral part of many of the goals of the other societal themes, and to the associated user communities. These efforts are especially related to: (1) terrestrial, coastal, and marine ecosystems, (2) understanding, assessing, and mitigating the impacts of climate variability and change, (3) identifying options for sustainable agriculture and reversing and combating land degradation and desertification, (4) promoting human health and well-being, (5) protecting water resources, and (6) understanding, monitoring, and preserving biological diversity.

Many organizations and government agencies need Earth observation data and models to forecast changes in important ecological resources and processes. These include city, county, and watershed organizations that are trying to evaluate smart growth options balanced by the vulnerability of ecological resources. There is also a need to evaluate near-term environmental conditions, as well as longer-term impacts and degradation. Other users will be managers of Federal, state, and tribal lands and waters charged with maintaining the viability of these areas and complying with the mandates of relevant environmental legislation, such as the Clean Water Act, Endangered Species Act, and National Environmental Policy Act.

Currently, there are a number of monitoring programs that collect information on biological, physical, and chemical attributes of ecosystems, some of which are regional and national in scale. Data from these programs have been used to develop, calibrate, apply, and refine ecological models.

One example of a successful and extremely relevant partnership can be found in the Multi-Resolution Land Characteristics (MRLC) consortium that was formed in 1992 between several U.S. Federal agencies in order to share the cost of acquiring satellite-based remotely-sensed data for their environmental monitoring programs. The MRLC resulted in the National Land Cover Data set and other successful programs, including the Coastal Change Analysis Project, the USGS National Water-Quality Assessment Program and the Gap Analysis Project.

Many observation systems are valuable. Radar system measurements are used to assess surface roughness, subsidence, three-dimensional aspects of vegetation canopies, biomass, and wetland extent. LIDARs represent another active sensing technology that holds much promise for the remote detection of vegetation structure and complexity, as well as biomass. LIDAR data can provide fine-scale estimates of vegetation canopy structure and elevation profiles, which are important input variables in ecological and hydrological process models as applied to relatively small areas

Hyperspectral measures are used to detect relatively fine-scale patterns of vegetation species distributions and structure, as well as the biochemical makeup of vegetation, soil, and surface waters. Some see the possibility of developing systems capable of remotely fingerprinting biological phenomena, in terms of both taxonomy and condition or health, arising from this technology.

Airborne digital multi-spectral photography provides vital information on vegetation characteristics, stream morphology, coral reef extent, coastline characteristics, and many other Earth and marine features and biophysical variables at relatively high spectral and spatial resolutions.

3. What Can't We Observe Now?

Forecasting is fundamental to understanding what needs to be done to avoid human and environmental disasters and to promote sustainable development. In this regard, forecasting plays an important role in early warning and risk assessment. Generally, managers, stakeholders, and decision-makers require two types of ecological forecasts: (1) short-term forecasts from 3-24 months and (2) longer-term forecasts from 5-50 years. Short-term forecasts give early warning of events and conditions that might affect key economic activities and human safety. These "near-real time" data are also used to target areas that need more detailed data collections. Long term forecasts are necessary to identify areas of high concern. The data required for these forecasts will come from observations which can typically fall into two general classes:

- spatially continuous biophysical data derived from remote-sensing and other sources
- field or site data on specific ecological and hydrologic processes and/or state variables

Site-specific data are needed to measure and estimate important ecological and hydrologic variables across space and time. These data can then be related empirically, via process or mechanistic models, to spatially continuous biophysical data. Gaps in data of these sorts can be categorized into six general classes: (1) field and site data (*in-situ*), (2) remotely-sensed and other spatial data, (3) modeling, (4) data and system interoperability/data standardization and management, (5) technology transfer, and (6) education and capacity building gaps. Each of these issues needs to be resolved in order to improve and extend our ability to conduct ecological forecasting.

There are also gaps in measurement variables, at a variety of scales that need to be addressed to improve ecosystem forecasting across the globe:

- vegetation indices, leaf area index, photosynthetically active radiation
- evapotranspiration, net photosynthesis and primary productivity
- land surface temperature and emissivity, fires and burning biomass
- land cover change and vegetation cover conversion, invasive species
- snow cover, sea ice cover
- ocean chlorophyll concentration, ocean chlorophyll fluorescence, and ocean primary productivity, and sea surface temperature
- marine and lake organic matter concentrations
- cloud characteristics from satellites

Other specific gaps and recommendations have been identified, here, and in other societal benefits areas. They include:

- Complete national digital databases on soils and geology at a scale of 1:100,000.
- Acquire *in-situ* and remotely-sensed data needed to measure status and changes in: (1) land cover and land use, (2) net primary land and oceanic productivity, (3) carbon balance, and (4) water balance.
- Deploy sensors that will measure the canopy structure of vegetation.
- Deploy sensors that will measure water quality and temperature for the wide range of water bodies across the U.S.
- Continued deployment of a SAR satellite platform.
- Continued deployment a comparable ocean color sensor.
- Digitize existing biological data using NBII taxonomic and other formal data standards.
- Standardize, convert and integrate existing biological and ecological data to easily accessible digital accessible formats.

Extensive research is being conducted at universities and institutes to integrate field and remotely-sensed data through development of dynamic, multi-scale process models. For example, there is a need for shorter-term forecasting (daily to monthly) in a direct sense at the local level where many decisions or scenarios are made. These forecasts should account for perturbations from large-scale atmospheric and other forcing variables. Current weather generators, which are commonly used to provide input to management and ecological models, could be improved by including perturbations and resulting influences.

4. How are we Addressing Gaps?

Satellite remote-sensing of the Earth's surface has only been in existence for just over 30 years, Archives of photographic imagery (while not contiguous at the national level) extend much further back in time to the early 1930s and 1940s. As such, they provide an invaluable time series for understanding landscape changes and associated phenomena. Preservation and digitization of these archives and the unique information they hold is of the utmost importance.

Although there are a number of deployed Earth observations systems across the U.S, including individual site monitoring stations and airborne and satellite imagery, lack of interoperability, coordination, and enforcement of Federal Geographic Data Committee (FGDC) data standards within and among these programs prevent optimal use of resulting data and information for ecological forecasting. New approaches in data mining and networking should improve data integration and modeling to a certain extent, but there are a number of issues related to data collection and availability that will limit the success of such programs. Certain types and scales of ecological forecasting are possible given current data and capabilities, and these are being pursued to fill gaps. For a more in-depth look at the state of Earth observations in the Ecosystems and Ecological Forecasting area, as well as for a list of references, please see the Ecosystems and Ecological Forecasting Reference Document on the IWGEO website at: http://iwgeo.ssc.nasa.gov.

Section 8: Protect And Monitor Water Resources

1. The State of Earth Observations for Protecting and Monitoring Water Resources

Earth observations for water availability and quality should include measurements of the fluxes and storage of water in a watershed and its underlying aquifer system; precipitation, streamflow, lake and reservoir storage, water quality, evaporation and transpiration, soil moisture, ground-water storage, ground-water recharge and discharge, and withdrawals for various uses should all be measured. Snowfall is of particular interest to water-resources managers because of the seasonal storage of water in the snowpack. Water quality concentrations and loads of various significant natural and anthropogenic contaminants must also be measured to determine their impact on water availability and on aquatic habitats in freshwater, estuarine, and marine environments. Most of these measurements must be made using *in situ* sensors, sampling, and manual measurement techniques, with only some available from remote-sensing. Temporal variability and long-term trends in these measures of availability must be recorded and documented.

Water Availability and Quality Functional Requirements:

- Continuity of operations
- Continuous, real-time data streams
- Rapid tasking of other data sources
- Global coordination of resources
- Rapid generation of accurate information and forecasts, and
- Efficient sharing of information products, in formats that are adapted to users' needs

2. What Can We Observe Now?

Observations for monitoring and protecting water resources are made by several Federal agencies. The observations include monitoring of fluxes and storage in the various components of the hydrologic cycle, and monitoring of chemical and biological characteristics of water resources. There are some examples of strong coordination and collaboration among agencies, but it is currently not possible to go to one single source for comprehensive water-resources monitoring information. Notable examples of water-resources monitoring programs are described below:

> **Precipitation** Precipitation quantity monitoring is done by NOAA using a combination of ground-based observation stations and remote-sensing. The stations provide national coverage at a resolution of about ¼ degree of latitude and longitude.
>
> **Snow** NOAA's National Operational Hydrologic Remote-sensing Center (NOHRSC) provides remotely-sensed and modeled hydrology products for the conterminous U.S. and Alaska. The national and regional snow analyses provide a daily synoptic overview of snow conditions for the conterminous U.S. as well as for the 18 U.S. snow regions at a higher resolution. The snow analyses are text descriptions of daily snow accumulation based on snow observations and modeled snowpack characteristics. NOHRSC provides both the meteorological observations of snowfall and snow on the ground as well as the snowfall and snow accumulation simulated by the NOHRSC snow model. Additionally, the U.S. Department of Agriculture installs, operates, and maintains an extensive, automated system called SNOTEL (SNOwpack TELemetry) to collect snowpack and related climatic data. The system measures snowpack in the mountains of the West and forecasts the water supply. The programs began with manual measurements of snow courses; but since 1980, SNOTEL has used telemetered data from 600 automated sensors in 11 western states including Alaska.
>
> **Precipitation Quality** The National Atmospheric Deposition Program coordinates an interagency network of 250 precipitation quality monitoring stations to monitor the acidity of precipitation as well as other constituents such as nitrates, sulfates, and ammonia. Annually the data are disseminated in several forms, including national maps.
>
> **Streamflow** The U.S. Geological Survey (USGS) operates a national network of about 7,000 telemetered stream gauges. This network is supported jointly

with other Federal, state, and local governments. The number of gauges in the network has been declining slightly in recent years as Federal and state budgets have become tighter. The database is updated about 8 times per year at each station.

Surface Water Quality There are numerous Federal, regional, state, tribal, and local monitoring programs for ambient surface water quality conditions and compliance monitoring. Most of these data are input to EPA's Storage and Retrieval (STORET) database. EPA summarizes state and Federal water-quality data biennally in the National Water Quality Inventory Report to Congress (305(b) report) to inform Congress and the public about general water quality conditions in the United States. This document characterizes water quality, identifies widespread water quality problems of national significance, and describes various programs implemented to restore and protect waters. It characterizes water body types (rivers, streams, creeks, lakes, ponds, reservoirs, bay, estuaries, coastal waters, oceans, and wetlands) as "good", "threatened", or "impaired", based on sampling results submitted by the states. The USGS also supports water quality monitoring programs: The National Water Quality Assessment (NAWQA) program is a nationwide monitoring and assessment tool that includes a network of 6,100 stream-quality monitoring sites. USGS also supports a program for modeling surface-water quality, titled SPARROW. This program relates in-stream water-quality measurements to spatially referenced characteristics of watersheds, including contaminant sources and factors influencing terrestrial and stream transport.

Suspended sediment is an important water-quality parameter that is a controlling factor for many total maximum daily load allocations, as well as for determining the useful lifespan of many dams and reservoirs. The USGS and several cooperating agencies have developed a suspended sediment database that provides daily concentrations and loads of sediment at many locations around the nation, plus ancillary data.

Lake and Reservoir Storage Data on lake and reservoir storage are included in the USGS National Water Information System as water-level data. Storage data are collected for individual projects by reservoir management agencies, typically using automated SCADA systems, but are not collected and reported on a national basis.

Evaporation and Transpiration NOAA collects and disseminates nationwide evaporation data based on observations at weather stations equipped with evaporation pans. Some excellent academic and government studies of evaporation and transpiration are underway.

Soil Moisture The USDA Natural Resources Conservation Service also monitors soil moisture as part of their Soil Moisture/Soil Temperature Pilot project (SM/STPP), and disseminates a limited set of soil moisture data for the U.S. via the Soil Climate Analysis Network. NOAA provides soil moisture that is estimated by a one-layer hydrological model using observed precipitation and temperature. These data are used for nationwide assessment and prediction purposes. A more sophisticated soil moisture product is the four-layer soil moisture estimate calculated in the Land Data Assimilation System (LDAS), based upon the NOAA four-layer land surface model. The North American LDAS is produced in real time at NOAA's National Center for Environmental Prediction, in collaboration with NASA and university partners. LDAS will lead to more accurate reanalysis and forecast simulations by numerical weather prediction (NWP) models, which typically have large errors in stores of soil moisture and energy and in turn, degrade the accuracy of forecasts.

Ground Water Storage The USGS maintains a network of wells to monitor the effects of droughts and other climate variability on ground-water levels. The network consists of a national network of about 150 wells. Some of these have real-time telemetry, some have continuous records obtained periodically during field visits, and some have periodic manual measurements.

Drought Monitoring The National Drought Mitigation Center at the University of Nebraska, in cooperation with NOAA, USDA, and other agencies, assembles drought-related data from many sources and provides them on a single web site. There are good efforts underway to extend this drought monitoring to cover all of North America. Several data products are provided, along with a combined drought monitor map for the U.S.

Ground Water Quality Monitoring of ground-water quality is spotty. Most states have programs for ambient ground-water quality monitoring, but they are not coordinated as a national network. The USGS National Water Quality Assessment (NAWQA), which includes ground water, has water-quality data from 7,000 wells in its data warehouse.

Ground-Water Recharge and Discharge These important components of the hydrologic cycle are usually estimated rather than measured directly. Availability and reliability of estimates varies greatly among U.S. aquifers.

Drinking Water The U.S. Environmental Protection Agency maintains several databases with nationwide information about drinking-water systems. The Safe Drinking Water Information System (SDWIS/FED) contains data about locations and characteristics of the Nation's public drinking water systems, and about violations of drinking-water standards or protocols. SDWIS/FED stores the information EPA monitors for approximately 175,000 public water systems. For data on concentrations of contaminants in drinking water, EPA maintains a National Contaminant Occurrence Database (NCOD). NCOD provides a library of water sample analytical data (or "samples data") that EPA is currently using and has used in the past for analysis, rulemaking, and rule evaluation. The drinking water sample data, collected at Public Water Systems, are for both regulated and unregulated contaminants. The data have been extensively checked for data quality and analyzed for national representative-ness. Within its National Water Quality Assessment Program, the USGS maintains a database of water quality data from domestic wells. Domestic wells are not regulated by EPA and do not contribute data to the EPA databases.

Land Use and Impervious Area Remote-sensing systems such as Landsat and MODIS provide spatial information covering certain aspects of land use that are of great importance in understanding, protecting, and predicting the quantity and quality of our water resources. The measurements include amounts and types of crops grown, the extent of irrigated land, the types of best-management practices employed to protect watersheds, various practices related to forestry, mining, grazing, and urbanization all affect water resources. Of particular interest is the extent of impervious or paved area in any given watershed, since impervious area retards infiltration and contributes to quicker runoff and higher storm peak flows in streams.

Wetlands The U.S. Fish and Wildlife Service monitors wetlands, which are an important component of the hydrologic system, both biologically and hydrologically. Wetland maps, developed through a combination of remote-sensing and ground-truth data, are available in a number of formats.

3. What Can't We Observe Now?

An important commonality of all of the surface-water related data mentioned above is the association of specific data with a specific section of a stream in a network where flow relationships (upstream and downstream) are known. This spatial information is the core of the National Hydrography Dataset (NHD), a collaboration of EPA and USGS. NHD is a digital depiction of the stream reach network of the entire country, with each reach connected to the network in such a way that flow relationships are known. In many cases, point data mentioned above are associated with individual stream reaches in the NHD. In other cases, this association has yet to be made. The NHD is the key to linking surface water data with other geospatial coverages important to hydrology, such as digital elevation models (which help to describe drainage area boundaries and stream slopes), watershed boundaries, land cover and land use, and impervious area.

One of the important gaps is the monitoring of lake and reservoir water quality, which was formerly coordinated and funded under the Clean Lakes Program. Some lake monitoring is encouraged under the implementation of section 319 of the Clean Water Act by EPA and state and local governments. Other areas are monitored by reservoir management agencies such as the Corps of

Engineers, the Bureau of Reclamation, the USGS, academic institutions, and other entities.

Ground water assessments need enhanced measurements, both in total ground water storage levels, and ground water quality. There are many thousands of monitoring wells that are measured by a variety of Federal, state, local, and tribal agencies, but there is little coordination of the monitoring programs. Most states have programs for ambient ground-water quality monitoring, but they are not coordinated as a national network.

4. How are we Addressing Gaps?

The report issued by the U.S. Commission on Ocean Policy and the U.S. Ocean Action Plan recommended the development of a national water quality monitoring network. Though a network of this type will require substantial coordination and resources, there is strong interest among participating agencies such as the USGS, EPA, and NOAA. A framework is being developed by the Advisory Committee on Water Information, through its National Water Quality Monitoring Council, that will provide a starting point towards the goal of a national network for water quality. This network would consist of *in-situ* measurements of specific constituents, complemented and supplemented by remotely-sensed data, to define the distribution and intensity of hypoxia, sea-grass loss, sedimentation, harmful algal blooms and other adverse conditions.

Soil moisture experiments are underway by the USDA and NASA to monitor soil moisture using remote-sensing satellites. Additionally, there is an effort underway using NASA's Aqua satellite and the Japanese ADEOS-II Advanced Microwave Scanning Radiometer to develop daily soil moisture products.

In the field of drought monitoring, NOAA has developed a plan, endorsed by the Western Governors Association, for a National Integrated Drought Information System that would provide enhanced monitoring capabilities, greater integration of data related to droughts, and enhanced forecasting capabilities. For a more in-depth look at the state of Earth observations in the Protecting and Monitoring Water Resources arena, as well as for a list of references, please see the Protecting and Monitoring Water Resources Reference Document on the IWGEO website at http://iwgeo.ssc.nasa.gov.

Section 9: Monitor And Manage Energy Resources

1. The State of Earth Observations for Monitoring and Managing Energy Resources

Observation systems for energy fall into three broad categories. The first set of observations relate to the Nation's consumption of energy. Energy consumption is tied significantly to weather and climate. Extremes of hot and cold weather seriously increase our energy consumption. Therefore, weather observations and prediction provide a tool for energy management. The second broad category is energy exploration. Earth observations are used extensively in the search for fossil fuels and are increasingly being used in the siting and development of renewable energy sources. The third broad category is observing the impacts of energy consumption, and these observations fall mainly within the realm of atmospheric characterization and climate change detection. The National Energy Policy outlines policies to enhance energy security while reducing greenhouse

Energy Resources Functional Requirements:

- Continuity of operations
- Continuous, real-time data streams
- Time scales of hours, days, seasons, years and decades
- Geographic scales including point source, regional, and global scale
- Efficient sharing of information products, in formats that are adapted to users' needs

gas emissions and recommends aggressively developing alternative fuels and hydrogen, advancing carbon sequestration technologies, and promoting energy efficiency and renewable energy.

2. What Can We Observe Now?

Observation systems are currently useful for detecting the consequences of energy consumption, for determining the availability of traditional energy resources, and for applicability of alternative energy sources and technologies. Responsibility for the operation of the currently deployed observing systems is summarized below, beginning with the most mature efforts:

> **Energy Supply, Consumption and End-Use Technologies** Measurement and monitoring systems provide the capability to evaluate the efficacy of efforts to reduce greenhouse gas emissions through the use of: (1) low-emission fossil-based power systems; (2) energy supply technologies that are reportedly greenhouse gas-neutral, such as biomass energy systems, geothermal, and other renewable energy technologies; and (3) end-use technologies for greater efficiencies. Observations needed to successfully fulfill these needs are: climate measurements, physical properties of Earth materials, meteorological measurements, hydrologic measurements, high-temperature sensors for emissions, fast-response mass spectrometry, continuous emissions monitors, and remote-sensing of emissions.
>
> **Energy Exploration and Development** Both satellite and *in situ* observations are used to identify patterns in geology, hydrology, and biology to aid in the location of favorable Earth habitats for fossil fuel occurrences or potential sites for renewable energy installations. Observations needs are geologic materials and structures, spectral reflectance thematic mapping of Earth surface materials, vegetation composition and patterns, and hydrologic flows and patterns.

Measurement and Monitoring of Greenhouse Gases This includes observations that: (1) provide inventories, concentrations and cross-boundary fluxes of CO_2 and other greenhouse compounds, including the size and variability of the fluxes; (2) provide data for determining the efficacy and durability of particular mitigation technologies or other actions, and for verifying and validating results; (3) provide data to evaluate the role of various technologies and strategies for mitigation by quantifying anthropogenic changes in sources and sinks of greenhouse gases; (4) provide data to identify opportunities and guide research investments in carbon markets; and (5) provide data to assess relationships among changes in greenhouse gas emissions, fluxes and inventories due to changes in surrounding environments. Observations required are atmospheric concentrations of CO_2 and co-emitted species, atmospheric CO_2 isotopic composition, eddy covariance measurements of CO_2 fluxes between land surface and atmosphere, forest biomass inventories, fossil fuels consumption records, remote-sensing, static and dynamic chambers. Observations besides CO_2 are atmospheric isotopic composition, eddy covariance measurements of fluxes between surface and atmosphere, forest biomass inventories, fossil fuels consumption records, and activity data (for example, cattle number and type, fertilizer mass use, landfill inputs, population for waste disposal).

Measurement and Monitoring of Carbon Storage and Sequestration Methods used to measure and monitor terrestrial sequestration of carbon address both the capture and retention of carbon in components of ecosystems. The measurements are used to evaluate net sequestration, greenhouse gas emissions that might occur from management practices and other environmental factors. Observations required are the soil carbon and nitrogen content, soil moisture content, standing biomass, atmospheric exchange of greenhouse gases, soil erosion, vegetation characterization, and soil survey.

Active Geothermal Energy Systems Measurements are used to identify solid Earth formation and rock constituents likely associated with geothermal power sources. Observations needed are the land surface/land cover, soil characterization, soil moisture, topography, strain monitoring, high resolution measurements of gravity and electric fields, physical properties of Earth materials, thermal emissions, water chemistry, and water discharges.

Renewable Energy Optimization Systems Renewable energy technologies include solar, wind and hydrological power. Estimating resources requires climatological information such as the duration of sunshine and solar elevation of an area, the cloudiness, the wind fields and the precipitation. Hydrological power also requires information about the water shed basin that drains into the river which is subsequently dammed for power production. Observations required in this area are meteorological measurements, cloud cover, solar radiation, precipitation, and hydrologic measurements.

3. What Can't We Observe Now?

Several areas identified for consideration in future portfolio planning for energy supply and consumption that deserve new or increased emphasis. These include: Improvements in performance, longevity, autonomy, spatial resolution of measurements, and data transmission of CEMs, along with the ability to measure multiple gases over broad geographic areas. More thorough process knowledge and life-cycle analysis are needed. Tower-mounted sensors, aircraft and satellite-based sensors for direct measurement of CO_2 and other gases or indicators, tracers, and isotopic ratios would be beneficial. There is a need for low cost, multiple wireless micro-sensor networks to monitor migration, uptake, and distribution patterns of CO_2 and other greenhouse gases in soil, forests, vehicles, and facilities. Data protocols and analytical methods for producing and archiving specific types of data to enable interoperability and long-term maintenance of data records, data production models, and emission coefficients that are used in estimating emissions require further development. Direct measurements are needed to replace proxies and estimates when direct measurements are more cost-effective in optimizing emissions and in better understanding the processes behind the formation of greenhouse gases.

Improvements are needed in the measurement and monitoring of Greenhouse Gases to include: techniques for measuring soil respiration and nocturnal fluxes, observations of land management, land cover and change, biomass burning, and deforestation. Measurements of greenhouse gas fluxes, observations of *in-situ* CH_4 oxidation, and process level models of N_2O production and indirect N_2O emissions are required on a global basis to fully understand impacts of land use/land cover and change. Additional research is also needed to effectively interpret observations. Development and testing of process-level models, linking between measurement and remotely-sensed observations, will all need to have global observations for validity.

Research topics identified for consideration in future research and development portfolio planning are categorized as follows: national implementation of a hierarchical system to quantify stocks, emissions, and sinks of CO_2 from the plot scale to the national scale; development of imaging and volume measurement sensors for land use/cover and biomass estimates; development of low-cost, practical methods to measure net carbon gain by ecosystems, and to conduct life cycle analysis of wood products; isotope markers to determine the source and movement of greenhouse gases in geological, terrestrial, and oceanic systems; and new measurement technologies that support novel sequestration concepts, such as enhanced mechanisms for CO_2 capture from free air, new sequestration products resulting from genome sequencing studies, and modification of natural biogeochemical processes.

4. How are we Addressing Gaps?

Partnership for Solar Energy Resource Assessment DOE and NASA have an established partnership to assess and improve solar resource mapping. Plans are being made for a task to be performed under the International Energy Agency involving DOE, NASA and 7 foreign nations (Germany, France, Spain, Italy, Portugal, Canada, and Japan). The task is planned to assess existing solar resource maps and to establish a criterion for the assessment of future predictions of solar resource on several different time scales. For predictions, NASA and NOAA will collaborate.

Partnership with Utility Companies Utility companies need to be able to predict demand loads with better accuracy. These demand load predictions are crucially dependent upon forecasts of weather and other parameters. Improved weather parameters will help to improve load forecasts and better anticipate peak demands. A partnership between NASA, NOAA and Electric Power Research Institute (EPRI) was initiated to accomplish such a task. NASA/NOAA will collaborate to provide recent past and forecast data in formats and with parameters important to the load forecasting problems.

Global R&D Satellites such as NASA's Earth Observation System research satellites and NOAA's operational weather and climate satellites, as well as NOAA's distributed ground network, which includes the Mauna Loa Observatory, are currently operational and support data gathering relevant to CCSP and CCTP. At present, Landsat 7 and Landsat 5 continue to collect spectral reflectance data for land cover and land change observations.

Continental R&D Ongoing research involves estimating net CO_2 emissions for the North American continent using different approaches: inversion analysis based on CO_2 monitoring equipment as currently arrayed, remote-sensing coupled with ecosystem modeling, and compilation of land inventory information. European researchers have embarked on a similar track by combining meteorological transport models with time-dependent emission inventories provided by member states of the European Union.

Regional R&D Advanced technologies, such as satellites, are monitoring and/or verifying countries' anthropogenic and natural emissions. NOAA is building an atmospheric carbon monitoring system under the CCSP using small aircraft and tall communications towers that will be capable of determining emissions and uptake on a 1000 km scale.

Local (micro or individual) R&D A number of techniques are currently used to directly or indirectly estimate emissions from individual sites and/or source sectors, such as mass balance techniques, eddy covariance methods (for example, at the AmeriFlux sites, where source identification is being done using isotope signatures), application of emissions factors derived from experimentation, forestry survey methods, and continuous emissions monitors in the utility sector.

In the long term, the envisioned approach is to evaluate data needs and pursue the development of an integrated overarching system architecture that focuses on the most critical data needs. Common databases would provide measurements for models that could determine sources and estimate additions to and removals from various greenhouse gas inventories, forecast the long-term fates of various greenhouse gases, and integrate results into relevant decision support tools and global-scale monitoring systems. This approach would include protocols for calibrated and interoperable (easily exchanged) data products, emissions accounting methods development, and coordination with basic science research in collaboration with CCSP. Tools would be validated by experimentation to benchmark protocols (to quantify the improvements that the tools provide), so that they would be recognized and accepted by the community-of-practice for emissions-related processes. For a more in-depth look at the state of Earth observations in the Monitoring and Managing Energy Resources area, as well as for a list of references, please see the Monitoring and Managing Energy Resources Reference Document on the IWGEO website at http://iwgeo.ssc.nasa.gov.

Summary

The goal of this appendix was to provide an Executive Summary of the associated technical reference documents for the nine societal benefit areas. It is not intended to be an exhaustive reference, but a link between the vision of the Strategic Plan and the state of observations in those areas. The technical reference documents are living documents, which will be updated on a regular basis with inputs from the Federal scientific community, as well as through public workshops and comment. It is hoped that the interested reader will go to the website and provide comments on these longer documents in addition to commenting on the Strategic Plan.

Additional technical documents on Architecture, Integration and Data Management are being developed by the Federal agencies and will be available for review in the near future.

List Of Acronyms

ADEOS	Advanced Earth Observation Satellite
ALOS	Advanced Land Observing Satellite
AUV	Autonomous Underwater Vehicle
AWRP	Aviation Weather Research Program
CCSP	Climate Change Science Program
CCTP	Climate Change Technology Program
CEMs	Continuous Emissions Monitors
CENR	Committee on Environment and Natural Resources
CLIVAR	Climate Variability and Predictability Programme
CrIS	Current Research Information System
DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense
DSS	Decision Support System
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
FEMA	Federal Emergency Management Agency
FGDC	Federal Geographic Data Committee
FHWA	Federal Highway Administration
GCOS	Global Climate Observing System
GEOSS	Global Earth Observation System of Systems
GFDL	Geophysical Fluid Dynamic Laboratory
GMAO	Global Modeling and Assimilation Office
GOOS	Global Ocean Observing System
GOS	Global Observing System
HHS	Health and Human Services
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research Project
IOOS	Integrated Ocean Observing System
IRIS	Incorporated Research Institutions for Seismology
ITWS	Integrated Terminal Weather System
IWGEO	Interagency Working Group on Earth Observations
JGOFS	Joint Global Ocean Flux Study
LDAS	Land Data Assimilation Systems
LIDAR	Light Detection and Ranging
LMR	Living Marine Resources
MDCRS	Meteorological Data Collection and Reporting System
MODIS	Moderate Resolution Imaging Spectroradiometer
MRLC	Multi-Resolution Land Characteristics Consortium
MSU	Microwave Sounder Unit
NAWQA	National Water Quality Assessment Program
NASA	National Aeronautics and Space Administration
NBII	National Biological Information Infrastructure
NCAR	National Center for Atmospheric Research

NCEP	National Centers for Environmental Prediction
NCOD	National Contaminant Occurrence Database
NDBC	National Data Buoy Center
NEOS	NOAA's Ecosystem Observation System
NESDIS	NOAA/National Environmental Satellite, Data & Information Service
NHD	National Hydrography Dataset
NIAID	National Institute of Allergy and Infectious Diseases
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NOAA	National Oceanic and Atmospheric Administration
NOHRSC	National Operational Hydrologic Remote-sensing Center
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NSIP	NWS Service Improvement Program
NSIPP	NASA Seasonal-to-Interannual Prediction Project
NWLON	National Water Level Observation Network
NWP	Numerical Weather Prediction
NWS	NOAA/National Weather Service
OFCM	Office of the Federal Coordinator for Meteorology
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PDTs	Product Development Teams
POES	Polar Operational Environmental Satellite
QuickSCAT	NASA's Quick Scatterometer
SDWIS	Safe Drinking Water Information System
SeaWiFS	Sea-viewing Wide Field of view Sensor
SM/STPP	Soil Moisture/Soil Temperature Pilot Project
SNOTEL	Snowpack Telemetry
SOLAS	Surface Ocean Lower Atmosphere Study
STIP	NWS Science and Technology Infusion Plan
STORET	EPA's Storage and Retrieval Database
THORPEX	The Hemispheric Observing System Research and Predictability Experiment
TOPEX	Ocean Topography Experiment
TRMM	Tropical Rainfall Measuring Mission
UAVs	Uninhabited Aerial Vehicles
USACE	U.S. Army Corps of Engineers
USAF	United States Air Force
USAID/OFDA	United States Agency for International Development/Office of U.S. Foreign Disaster Assistance
USGS	United States Geological Survey
USWRP	U.S. Weather Research Program
VIRS	Visible and Infrared Scanner
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WRF	Weather Research and Forecasting Model

APPENDIX 3:
END NOTES

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[10] van der Vink, G., *et al.,* "Why the United States is Becoming More Vulnerable to Natural Disasters," *Eos,* Transactions, American Geophysical Union, Vol. 79, No. 44, November 3, 1998, pp. 533, 537.

[11] *See* Appendix 2.

[12] *Ibid.*

[13] Cicerone, Ralph J., et al., *Climate Change Science: An Analysis of Some Key Questions,* National Research Council, 2001, National Academy Press, pp 23, 24.

[14] *See* Appendix 2.

[15] *Ibid.*

[16] *Ibid.*

[17] *Ibid.*

[18] *Ibid.*

[19] Jones, Del, USA Today, "Forecast: 1 degree is worth $1B in power savings," June 19, 2001.

[20] See the GLOBE website at http://www.globe.gov/fsl/welcome.html.

[21] The Clinger-Cohen Act of 1996 assigned Agency Chief Information Officers (CIO) with the responsibility to develop information technology architectures (ITAs). The Office of Management and Budget (OMB) M-97-02, Funding Information Systems Investments, October 1996, requires that Agency investments in major information systems be consistent with Federal, Agency, and Bureau ITAs. The CIO Council began developing the Federal Enterprise Architecture Framework in April 1998 to promote shared development for common Federal processes, interoperability, and sharing of information among the Agencies of the Federal Government and other Governmental entities.

[22] Statistical Abstract of the United States 2000, p. 38, U.S. Census Bureau

[23] See for instance, the Data Management and Communications System in the Integrated Ocean Observing System at http://dmac.ocean.us/dacsc/imp_plan.jsp and the National Model Access Data System.

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[29] Earth System Modeling Framework, found at http://www.esmf.ucar.edu/

[30] "The Ozone Report—Measuring Progress Through 2003," EPA454/K-04-001, April, 2004.

Photo Credits

ii	Snowmelt runoff fills a reservoir in the Rocky Mountains near Dillon, Colorado. Photo by Scott Bauer, USDA.
viii	A healthy wheat field outside Clay Center, Nebraska. Photo by Stephen Ausmus, USDA.
8	Secretary of State Colin Powell addresses participants at Earth Observation Summit I. Also seated at the dais from L-R are NOAA Administrator Conrad Lautenbacher, Energy Secretary Spencer Abraham, Commerce Secretary Don Evans, White House Science Advisor John Marburger, Council on Environmental Quality Chairman James Connaughton, Republic of the Congo Minister Henri Djombo, and Under Secretary of State Paula Dobriansky. Photo provided by NASA.
12	NOAA-12 multi-channel image of Hurricane Bonnie, August 1998. Satellite designed and built by NASA and is NOAA operated.
30	Deep-ocean Assessment and Reporting of Tsunamis (DART) buoy servicing aboard NOAA ship, HI`IALAKAI. Photo by Stephen Barry, NOAA.
34	SERVIR training workshop at Marshall Space Flight Center. SERVIR is a Regional Monitoring and Visualization System for Mesoamerica that intensively utilizes satellite imagery and other data sources for environmental management and disaster support. NASA Photo by Emmett Given.
44	NOAA's National Severe Storm Lab's first research Doppler Weather Radar. Photo provided by NOAA Photo Library, NOAA Central Library; OAR/ERL/National Severe Storms Laboratory (NSSL).
56	Technician Jeff Nichols collects a water sample from the Walnut Creek watershed in Ames, Iowa. Photo by Keith Weller, USDA.
58	Atmospheric Radiation Measurement's facility at Barrow, AK, is providing data about cloud and radiative processes at high latitudes. These data are being used to refine models and parameterizations as they relate to the Arctic. Photo provided by DOE's Photo provided by DOE's Atmospheric Radiation Measurement Program..
68	Aerographer's mate launching weather balloon. Official U.S. Navy photo provided by DOD.
141	Analysis Atmospheric Radiation Measurement (ARM) Mobile Facility site to be deployed at Niamey, Niger in 2006 (http://www.arm.gov/acrf). Photo provided by DOE's Atmospheric Radiation Measurement Program.
144	Waves coming in at Port Elliot, Encounter Bay, South Australia. Photo provided by Chris Potter.

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