NATIONAL PLAN FOR CIVIL EARTH OBSERVATIONS

PRODUCT OF THE

National Science and Technology Council
Executive Office of the President

July 2014

EXECUTIVE OFFICE OF THE PRESIDENT

NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

WASHINGTON, D.C. 20502

July 18, 2014

Dear Members of Congress:

The United States Government collects and distributes a wide range of environmental and Earth-system data. These data, collected and maintained through billions of dollars of investments in civil Earth observation systems, provide decision makers with information vital to improving our lives and well-being, protecting property, promoting national security and economic growth, and advancing scientific inquiry. The observations that provide these data are critical to our understanding of all Earth-system phenomena, including weather and climate, natural hazards, land-use change, ecosystem health, and natural-resource availability.

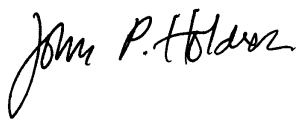
Legislation instructs the Director of the Office of Science and Technology Policy (OSTP) to establish a mechanism to ensure greater coordination of civilian Earth observations, including the development of a strategic implementation plan that is updated at least every three years. In April 2013, the National Earth Observations Task Force completed the National Strategy for Civil Earth Observations, which established a policy framework for routine assessment of Earth observations and guidelines to facilitate enhanced data management and information delivery to users. It also called for the development of a National Plan for Civil Earth Observations.

This first-ever National Plan is a key outcome of interagency coordination in support of the National Strategy. Based in large part on the results of a government-wide assessment of the Nation's Earth observations portfolio, the Plan establishes priorities and supporting actions for advancing our civil Earth observations capabilities. Its publication marks an important step in our ability to understand, prioritize, and coordinate Federal Earth observations and to better inform our investments in civil Earth-observation systems.

The Plan was developed by OSTP through an interagency effort led by the U.S. Group on Earth Observations, a subcommittee of the National Science and Technology Council's Committee on Environment, Natural Resources, and Sustainability. It will be revised every three years in conjunction with the regular Earth observations assessment process.

I and my office look forward to working with the Congress to support the Plan's implementation and to advance our civil Earth-observation capabilities for the benefit of society.

Sincerely,



John P. Holdren
Assistant to the President for Science and Technology
Director, Office of Science and Technology Policy

About the National Science and Technology Council

The National Science and Technology Council (NSTC) is the principal means by which the Executive Branch coordinates science and technology policy across the diverse entities that make up the Federal research and development enterprise. A primary objective of the NSTC is establishing clear national goals for Federal science and technology investments. The NSTC prepares research and development strategies that are coordinated across Federal agencies to form investment packages aimed at accomplishing multiple national goals. The work of the NSTC is organized under five committees: Environment, Natural Resources, and Sustainability; Homeland and National Security; Science, Technology, Engineering, and Math (STEM) Education; Science; and Technology. Each of these committees oversees subcommittees and working groups focused on different aspects of science and technology. More information is available at http://www.whitehouse.gov/ostp/nstc.

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976. OSTP's responsibilities include: advising the President in policy formulation and budget development on questions in which science and technology are important elements; articulating the President's science and technology policy and programs; and fostering strong partnerships among Federal, state, and local governments, and the scientific communities in industry and academia. The Director of OSTP also serves as Assistant to the President for Science and Technology and manages the NSTC. More information is available at http://www.whitehouse.gov/ostp.

About the United States Group on Earth Observations

The United States Group on Earth Observations (USGEO) is chartered as a subcommittee of the NSTC Committee on Environment, Natural Resources, and Sustainability (CENRS). The Subcommittee's purpose is threefold: to coordinate, plan, and assess Federal Earth observation activities in cooperation with domestic stakeholders; to foster improved Earth system data management and interoperability throughout the Federal Government; and to engage international stakeholders by formulating the U.S. position for, and coordinating U.S. participation in the intergovernmental Group on Earth Observations. More information is available at http://www.usgeo.gov.

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About this Document

This Plan was developed by OSTP with the support of a writing team led by USGEO Subcommittee Chair, Peter Colohan, and Director of the USGEO Program, Timothy Stryker. It was reviewed by the USGEO Subcommittee and CENRS and was finalized and published by OSTP.

OSTP and the USGEO Subcommittee and Program wish to acknowledge the significant analytical contributions of staff from the Institute for Defense Analyses (IDA) Science and Technology Policy Institute throughout the development of the Plan, including Jason Gallo, Brian Sergi, Eoin McCarron, and Elaine Sedenberg.

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*Stepped down in 2014 [A2]

Table of Contents

Executive Summary

The U.S. Government is the largest provider of environmental and Earth-system data in the world. These data are derived from observations of the Earth, which are used by Federal agencies and their partners to carry out their missions. These data form the foundation of services that protect human life, property, the economy, and national security, and they support research to foster scientific advances. Provided through public funding, they are made open to the greatest extent possible to advance human knowledge, to enable private industry to provide value-added services, and for general public use.

As the Nation's Earth-observation capacity and related data holdings have grown, so has the complexity of the challenge of managing Earth observation systems effectively and taking full advantage of the data they collect. While Earth observations and data are often collected to support the delivery of well-defined products and public services or meet specific research needs, improved coordination and access would ensure that the data are used more broadly. By expanding the use of observations and data beyond the purposes for which they are originally collected, the United States can maximize the impact of the resources invested in Earth-observation systems.

In October 2010, Congress charged the Director of the Office of Science and Technology Policy (OSTP) with establishing a mechanism for addressing this challenge through the production and routine update of a strategic plan for Earth observations. In response, OSTP convened a National Earth Observations Task Force (NEOTF) in February 2011, which produced the National Strategy for Civil Earth Observations in April 2013. The NEOTF also conducted the first assessment of the Federal Earth observations enterprise. The resulting Earth-Observation Assessment (EOA) considered the impact of observing systems on distinct societal benefit areas.

This document, the *National Plan for Civil Earth Observations* (hereafter referred to as the National Plan), incorporates the priorities identified in the EOA to provide strategic guidance for a balanced portfolio approach to managing civil Earth observations to fulfill agency mandates and achieve national objectives. As required by law, this National Plan will be updated every three years to provide greater coordination of Federal civil Earth-observation systems.

The National Plan defines a new framework for constructing a balanced portfolio of Earth observations and observing systems. This framework classifies Earth-observation activities according to two broad categories, "sustained" and "experimental" based on the duration of the anticipated Federal commitment:

- Sustained observations are defined as measurements taken routinely that Federal agencies are committed to monitoring on an ongoing basis, generally for seven years or more. These measurements can be for public services or for Earth-system research in the public interest.
- Experimental observations are defined as measurements taken for a limited observing period, generally seven years or less, that Federal agencies are committed to monitoring for research and development purposes. These measurements serve to advance human knowledge, explore technical innovation, and improve services, and in many cases may be first-of-their-kind Earth observations.

Within the subcategory of sustained observations for public services, the National Plan defines two tiers of measurement groups. Tier 1 measurement groups are those derived from systems identified in the EOA as having high impact on a majority of the societal benefit areas; Tier 2 measurement groups include those derived from the remaining high-impact systems. While the EOA provided higher overall scores to Tier 1 systems, many Tier 2 systems contribute critically, or are essential, to key objectives in one or more societal benefit areas. Some Tier 2 systems are the only observing systems available for accomplishing a particular objective.

These new categories advance the Nation's approach to Earth observations by describing a new framework based on the duration of Federal commitment to the period of observation, which is an essential step for prioritizing the Nation's Earth observations portfolio. This framework is also a step toward addressing a key policy challenge in Earth observations: determining when experimental observations should be transitioned to sustained observations for research or for delivery of public services.

Based on this framework and the results of the EOA, the National Plan establishes the following rank-ordered priorities:

1. Continuity of sustained observations for public services
2. Continuity of sustained observations for Earth-system research
3. Continued investment in experimental observations
4. Planned improvements to sustained observation networks and surveys for all observation categories
5. Continuity of, and improvements to, a rigorous assessment and prioritization process

The overall set of observations resulting from these priorities should yield a balanced Earth-observations portfolio.

While the National Plan provides guidance in setting priorities for the construction of the portfolio, agencies have discretion, in consultation with the Executive Office of the President and Congress, to deviate from the National Plan's rankings of priorities when necessary for managing specific systems in the categories and tiers outlined in this document. The National Plan provides this flexibility while still meeting the Nation's overall civil Earth-observation priorities and objectives.

The National Plan also identifies the following rank-ordered supporting actions that will maximize the benefits derived from the Nation's Earth observations:

1. Coordinate and integrate observations
2. Improve data access, management, and interoperability
3. Increase efficiency and cost savings
4. Improve observation density and sampling
5. Maintain and support infrastructure

6. Explore commercial solutions
7. Maintain and strengthen international collaboration
8. Engage in stakeholder-driven innovation

The National Plan also describes specific agency roles and responsibilities for sustaining observation systems and platforms.

Implementation and coordination of the activities outlined in the National Plan will be conducted through the budget and program-planning activities of the relevant Federal agencies and through interagency processes. Federal agencies will determine implementation schedules, progress reviews, and funding profiles in consultation with the Executive Office of the President.

The primary forum for interagency discussion and coordination of Earth observation, related data management, and related international issues is the United States Group on Earth Observations (USGEO) Subcommittee of the National Science and Technology Council (NSTC) Committee on Environment, Natural Resources, and Sustainability (CENRS). OSTP, in consultation with the USGEO Subcommittee, the NSTC CENRS, and their member agencies, will review and update this National Plan on a three-year cycle. As part of the update process, OSTP will solicit and consider the input of external stakeholders and the general public. For this first National Plan, OSTP sought input from external stakeholders through a publicly released Request for Information.

1. Introduction

The U.S. Government the largest provider of environmental and Earth system data in the world. These data are derived from Earth observations[1] collected by numerous Federal agencies and partners to carry out their missions in support of life, property, and economic and national security, and they are the foundation for scientific advances**.** In accordance with the *National Strategy for Civil Earth Observations* and Executive Order No. 13642, these publicly funded data are made open[2] to the greatest extent possible to advance human knowledge, to enable private industry to provide value-added services, and for general public use.[3]

Conservative estimates indicate that Federal Earth-observation activities add $30 billion to the U.S. economy each year.[4] These investments ensure that decision makers, businesses, first responders, farmers, and an array of other stakeholders have the information they need about natural resources, climate and weather, natural hazards, land-use change, ecosystem health, water, and other characteristics of the planet. Taken together, Earth observations provide the indispensable foundation for meeting the Federal Government's long-term sustainability objectives and advancing U.S. social, environmental, and economic well-being.

As the Nation's Earth-observation capacity has grown, however, so has the complexity and challenge of its most effective use for public benefit. Today, civil Earth observations are funded in the budgets of 11 departments and agencies of the Federal Government, including more than an estimated $2.5 billion in satellite systems and more than $1 billion for airborne, terrestrial (including freshwater), and marine networks and surveys (e.g., buoys, stream gages, and fishery surveys). U.S. Earth observation efforts are

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[1] The term "Earth observations" refers to data and products derived from Earth-observing systems and surveys. The term "observing systems" refers to one or more sensing elements that directly or indirectly collect observations of the Earth, measure environmental parameters, or survey biological or other Earth resources (land surface, biosphere, solid Earth, atmosphere, and oceans). A more detailed definition is provided in Section 2: Definitions and Context.

[2] National Earth Observations Task Force, *National Strategy for Civil Earth Observations*, Washington, DC: Office of Science and Technology Policy, April 2013, p. 24, http://www.whitehouse.gov/sites/default/files/microsites/ostp/nstc_2013_earthobsstrategy.pdf; Executive Order No. 13642 "Making Open and Machine Readable the New Default for Government Information," May 9, 2013, http://www.whitehouse.gov/the-press-office/2013/05/09/executive-order-making-open-and-machine-readable-new-default-government-.

[3] Defense and national-security requirements and considerations are not covered by this National Plan, though the use of defense and national-security assets for civil purposes is included. The Department of Defense is responsible for developing solutions for defense Earth observation requirements to support military operations and makes data available for civil agency use as appropriate. Coordination and oversight of civil agency use of national-security classified collections is performed by the interagency Civil Applications Committee. See the National Earth Observations Task Force, *National Strategy for Civil Earth Observations*, Washington, DC: Office of Science and Technology Policy, April 2013, p. 13.

[4] *Earth Observations and Global Change*, Center for Strategic and International Studies (CSIS), 2008, p. 10. http://csis.org/files/media/csis/pubs/080725_wigbels_earthobservation_web.pdf.

distributed among more than 100 programs under the purview of Federal agencies and non-Federal entities that produce and use these data.[5]

While Earth-system data collected through these observations are currently used to meet critical needs of distinct organizations and stakeholders, improved coordination will ensure that information derived from Earth observations will be used more broadly for both traditional and innovative purposes.

In October 2010, Congress charged the Director of the Office of Science and Technology Policy (OSTP) with establishing a mechanism for addressing this challenge.[6] OSTP convened a National Earth Observations Task Force (NEOTF) in February 2011 under the National Science and Technology Council (NSTC) Committee on Environment, Natural Resources, and Sustainability (CENRS) to inform the OSTP response to Congress. The NEOTF took three actions:

1. The development of a *National Strategy for Civil Earth Observations* (hereafter referred to as the National Strategy) to provide an enduring framework for routine assessment and planning for the Nation's Earth observation infrastructure. The National Strategy was released in April 2013.[7]

2. The development of a data-management framework, including principles and guidelines to improve discovery, access, and use of Earth observations. This framework is contained within the National Strategy.

3. The first assessment of the Federal Earth-observation enterprise, reviewing the impact of 362 observing systems on 13 societal themes. Summary results of the 2012 Earth Observation Assessment (EOA) are presented in this National Plan for Civil Earth Observations (hereafter referred to as the National Plan).

These three actions provided OSTP and CENRS with the foundation for this National Plan, which includes the following elements:

1. Definitions and context (Section 2)

2. Categories for civil Earth observations (Section 3)

3. Priorities and supporting actions for civil Earth observations (Section 4)

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[5] Non-Federal entities encompass State, regional, local, and tribal governments; nongovernmental organizations; academia; citizen scientists; commercial firms; international organizations; and foreign governments.

[6] National Aeronautics and Space Administration Authorization Act of 2010 (Public Law 111–267):
SEC. 702. INTERAGENCY COLLABORATION IMPLEMENTATION APPROACH. -The Director of OSTP shall establish a mechanism to ensure greater coordination of the research, operations, and activities relating to civilian Earth observation of those Agencies, including NASA, that have active programs that either contribute directly or indirectly to these areas. This mechanism should include the development of a strategic implementation plan that is updated at least every 3 years, and includes a process for external independent advisory input. This plan should include a description of the responsibilities of the various Agency roles in Earth observations, recommended cost-sharing and procurement arrangements between Agencies and other entities, including international arrangements, and a plan for ensuring the provision of sustained, long-term space-based climate observations. The Director shall provide a report to Congress within 90 days after the date of enactment of this Act on the implementation plan for this mechanism.

[7] National Earth Observations Task Force, *National Strategy for Civil Earth Observations*, Washington, DC: Office of Science and Technology Policy, April 2013.

4. Agency roles and responsibilities for sustained observations from airborne, terrestrial, and marine platforms (Section 5)
5. Agency roles and responsibilities for civil Earth observations from space (Section 6)
6. Summary guidelines on implementation and coordination of the National Plan (Section 7)
7. Summary results from the 2012 EOA supporting the identified priorities, EOA caveats, and a list of abbreviations used in this document (Annexes I-III).

As required by law, this National Plan will be updated every three years to ensure greater coordination of Federal civil Earth observation systems.

This National Plan serves as strategic guidance and sets out to fulfill agency mandates and national objectives via a balanced portfolio approach to civil Earth observations. The National Plan provides a framework that allows for the establishment, evaluation, and evolution of a balanced portfolio of observations and observing systems. This new framework builds on recent progress Federal agencies have made in taking fuller advantage of Earth observations across traditional boundaries to address their mission objectives and policy goals.

2. Definitions and Context

The National Strategy defined key terms and concepts for routine assessment and planning for Earth observations. These and other definitions are used throughout the National Plan.[8]

2.1. Definition of Earth Observations and Earth Observing Systems

"Observation" refers to the act of making and recording the measurement of a phenomenon. "Earth observations" are described in the National Strategy as follows:

> The term "Earth observations" refers to data and products derived from Earth-observing systems and surveys. The term "observing systems" refers to one or more sensing elements that directly or indirectly collect observations of the Earth, measure environmental parameters, or survey biological or other Earth resources (land surface, biosphere, solid Earth, atmosphere, and oceans).[9] Sensing elements may be deployed as individual sensors or in constellations or networks and may include instrumentation or human elements. Observing-system platforms may be mobile or fixed and are space-based, airborne, terrestrial, freshwater, or marine-based.

Earth observations are increasingly provided by integrated systems that support remotely sensed, in situ, and human observations. The benefit of these observations comes from the analysis of Earth-system parameters from different geographic or temporal perspectives, providing more complete monitoring of the target phenomenon and its interaction with other phenomena.

2.2. Societal Benefit Areas (SBAs)

The National Strategy laid out a process to evaluate Earth-observing systems based on the information products and data streams they support in defined SBAs. This approach was adopted by the NSTC CENRS in February 2012, is consistent with the Federal Government's sustainability objectives, and aligns with international agreements and prior interagency work in this area.[10] The first assessment of Earth observations was organized around 13 societal themes, which consisted of 12 SBAs (listed alphabetically below) and the reference measurements that underpin them:

- **Agriculture and Forestry**: Supporting sustainable agriculture and forestry
- **Biodiversity**: Understanding and conserving biodiversity

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[8] This National Plan contains both bulleted and numbered lists. Numbered lists indicate the order of priority, whereas bulleted lists indicate equal priority.

[9] Model outputs are generally excluded from this definition; however, some observing systems produce and record measures and observations that may require sensor models to process raw observations to a form in which they are exploitable.

[10] Group on Earth Observations, *Global Earth Observation System of Systems (GEOSS): 10-Year Implementation Plan Reference Document*, 2005, http://www.earthobservations.org/documents/10-Year%20Plan%20Reference%20Document.pdf; Interagency Working Group on Earth Observations, *Strategic Plan for the U.S. Integrated Earth Observation System*, NSTC Committee on Environment and Natural Resources, 2005, http://www.whitehouse.gov/sites/default/files/microsites/ostp/eocstrategic_plan.pdf .

- **Climate**: Understanding, assessing, predicting, mitigating, and adapting to climate variability and change
- **Disasters**: Reducing loss of life, property, and ecosystem damage from natural and human-induced disasters
- **Ecosystems (Terrestrial and Freshwater)**: Improving the management and protection of terrestrial and freshwater ecosystems
- **Energy and Mineral Resources**: Improving the identification and management of energy and mineral resources
- **Human Health**: Understanding environmental factors affecting human health and well-being
- **Ocean and Coastal Resources and Ecosystems**: Understanding and protecting ocean, coastal, and Great Lakes populations and resources, including fisheries, aquaculture, and marine ecosystems
- **Space Weather**: Understanding, assessing, predicting, and mitigating the effects of space weather on technological systems, including satellites, power grids, communications, and navigation
- **Transportation**: Improving the safety and efficiency of all modes of transportation, including air, highway, railway, and marine
- **Water Resources**: Improving water-resource management through better understanding and monitoring of the water cycle
- **Weather**: Improving weather information, forecasting, and warning
- **Reference Measurements**: Improving reference measurements—the underpinnings of all SBAs—such as geodesy, bathymetry, topography, geolocation, timing, and the fundamental measurement systems and standards supporting them

These SBAs are interconnected at local, regional, national, and international scales and include scientific research, economic activities, and environmental and social domains. Many involve critical government functions, such as the continuity of national government and the protection of life and property.

2.3. Earth Observation Assessment (EOA)

The first EOA was conducted between February and August 2012 under the auspices of the NEOTF. The NEOTF principals designated a working group to collaborate with appropriate subject matter experts (SMEs). OSTP reached out to the subcommittees of CENRS to identify the 13 subject matter leads, who in turn recruited over 300 Federal experts to participate in 26 analytical workshops.

This EOA quantified the impacts of existing observing systems on a set of key objectives defined for each SBA listed in Subsection 2.2. This resulted in the identification of 362 observing systems and surveys, of which 145 were designated as “high impact.” Results for the high-impact systems were grouped in tiers

and ordered based on a numeric impact score derived through the assessment process. These results are presented in Annex I.[11]

The EOA provided two new perspectives to complement the work of previous studies in this area, namely (a) the inclusion of non-satellite systems and (b) a robust analysis of the impact of each system with respect to its delivery of services to society.[12]

The next EOA, which is planned to begin in 2014, will seek additional insight with regard to research priorities and future needs in addition to existing systems.

2.4. Data-Management Framework, Big-Earth-Data Initiative, and Climate Data Initiative

While Earth observations are typically produced for a specific purpose, they are often useful for purposes not foreseen during their development. Earth observation data can be reused, managed, and preserved such that both anticipated and unanticipated users can find, evaluate, understand, and use the data in new ways to achieve added benefit. The National Strategy, therefore, set out a comprehensive data-management framework to promote improved discoverability, accessibility, and usability of Earth observation data.

The National Plan includes improving data access, management, and interoperability as a supporting action. The Big Earth Data Initiative (BEDI) is designed to support this objective (see Section 4.2.2). In addition, the President's Climate Action Plan[13], announced in June 2013, launched a Climate Data Initiative to leverage extensive Federal climate-relevant data to stimulate innovation and private-sector entrepreneurship in support of climate resilience.

2.5. Relationship between the National Plan and Existing Studies

The National Plan can be understood as the first in a series of interagency efforts to analyze Federal-Earth observation priorities. It can also be understood in connection with other internal and external assessments. Of these assessments, an important example is the 2007 National Academies report, *Earth Science and Applications from Space*, known as the Earth Science decadal survey. This and other reports of the National Academies provide substantial material for understanding Earth-observation priorities of

[11] See the National Strategy for a complete description of the assessment process.

[12] The EOA provided an innovative approach to understanding the impacts of Federal Earth-observation systems. The results of the EOA, however, must be considered in the context of the limitations of this assessment, which is the first of its kind. For example, fundamental research about the Earth system underpins each of the 12 SBAs, and each team was invited to consider research priorities critical for its area. The EOA process, however, was fundamentally service-oriented, and the constraints of time and the breadth of the analysis prevented a full accounting of research needs in every area. Therefore the EOA's results for research observation systems may not reflect the full impact of those systems on climate and other research needs. See Annex II for a full list of caveats.

[13] Executive Office of the President, *The President's Climate Action Plan*, 2013, http://www.whitehouse.gov/share/climate-action-plan.

the research community. This National Plan was informed by the results of the EOA, by these reports, and by related interagency deliberation.

2.6 External Input and the Request for Information

In developing this first National Plan, OSTP sought input from external stakeholders through a Request for Information (RFI).[14] Issued in November of 2013, the RFI solicited input on the major themes, categories, and priorities for the National Plan. OSTP received responses from a range of stakeholders, including individuals, academic institutions, private-sector companies, and industry organizations. Using both qualitative and quantitative approaches, OSTP analyzed the RFI responses and incorporated input into the National Plan where appropriate. OSTP will seek and incorporate external input in future editions of the National Plan.

[14] Office of Science and Technology Policy, *National Plan for Civil earth Observations; Request for Information*, Office of the Federal Register, 2013, https://www.federalregister.gov/articles/2013/11/12/2013-26890/national-plan-for-civil-earth-observations-request-for-information; see the USGEO web page for a list of public responses to the RFI for the development of the National Plan for Civil Earth Observations, http://www.whitehouse.gov/administration/eop/ostp/library/shareyourinput/earthobsrfi.

3. Categories for Civil Earth Observations

3.1. Overview of Categories

The National Plan defines two categories of observations that reflect the intention to distinguish systems and programs based on the duration of Federal commitment to the period of observation: either sustained over time or experimental and therefore time-limited. Sustained observations may be used to support public services and research for the public interest. Experimental observations may be used to support a variety of purposes, including: advancing human knowledge through basic and applied research, exploring technical innovation, or improving public services.

A fundamental goal of this National Plan is to achieve a balanced portfolio across and within both sustained and experimental categories of observations. Any Federal agency may engage in sustained and experimental observations to meet its mandate, achieve specific missions, or to support national objectives. These new categories of observation are designed to provide clarity in the Nation's approach to Earth observations. This categorization, based on the duration of commitment, is necessary for prioritizing the Nation's Earth-observing portfolio.[15]

This National Plan recognizes, however, that all civil Earth observations collected by the public sector are considered public goods, and that data from systems in any one category may be reused for purposes other than those for which the observation was originally taken. Such reuse is enabled by the rapid exchange and integration of data made possible by modern information technology (see Subsection 2.4 on data management).

For example:

- Sustained observation systems supporting the delivery of public services contribute significant data and information to both short- and long-term research programs.
- Sustained observation systems for research, as well as experimental observation systems, provide data and information that are routinely exploited in support of the ongoing, regular delivery of public services.
- Experimental observation systems supported by research and development funds can yield new systems or observation capabilities that can then be applied to service-driven observation programs.

[15] By focusing on duration, this new framework overcomes the conceptual limitations of the traditional categories of "research" and "operational" observations, which conflate three elements of Earth observation planning: purpose, duration, and state. The purpose of the system reflects the rationale for the agency's deployment of the system—to deliver public services or to conduct research in the public interest (including basic research). Duration reflects the time period over which the agency intends to perform the observation. State refers to the status of an observing system as it evolves—from testing, through development, to operations—no matter the intended purpose or duration of the agency commitment to the observation system. Whereas research clearly refers to purpose, the term "operational" has come to mean purpose, duration, and state, particularly in the defense and aerospace communities, in the sense of "supporting ongoing operations." Under the National Plan's new framework, civil Earth observation systems previously characterized as "operational" are included under "sustained observations for public services."

While recognizing the value of data across all categories, this approach to categorizing observing systems as either sustained or experimental is a step toward addressing a key policy challenge: determining when experimental Earth observations should be transitioned to sustained observations for research or to help deliver public services. This transition may occur within or between agencies. The policy challenge is greatest in the case of multi-agency collaboration. By recognizing that multiple agencies engage in both experimental and sustained observations, the new terminology for sustained observations allows for long-term measurement responsibilities and plans to be more easily and accurately characterized within individual agency budgets.

This National Plan acknowledges the outstanding need to address cross-agency, experimental, and sustained observation challenges, and it initiates an interagency process for establishing government-wide priorities for sustained observations, either for service or research purposes.

3.2. Sustained Observations

For the purposes of this National Plan, sustained observations are defined as measurements that Federal agencies are committed to taking on an ongoing basis, generally for seven years or more, at a level of quality sufficient for the primary purpose for which the measurement is taken.[16] Such long-term commitments include pre-planned improvements and service-life extension programs. Sustained observations are divided into two purpose-driven subcategories: those for public services and those for Earth system research for the public interest. These subcategories are further described in the following two subsections.

3.2.1. Sustained Observations for Public Services

Sustained Observations for Public Services are those systematic measurements necessary to support products routinely generated for, and widely disseminated to, the general public. These include vital measurements supporting continuous data streams and data products for preservation of life and property (e.g., for severe weather, seasonal and inter-annual climate forecasts, earthquakes, volcanoes, tsunamis, floods, fire detection and suppression, and air quality alerts); routinely generated current conditions data (e.g., for transportation, agriculture, energy, and weather forecasting); and data relating to ongoing resource and environmental management (e.g., for trends analysis, stock assessments, water quality, and forestry).

The Earth-observation systems that produce these sustained observations constitute vital national infrastructure, providing well-established, direct benefits to society and the economy (e.g., protecting life and property and securing food and water during disasters). These systems are in place to provide the Nation with essential information to promote and sustain economic vitality (e.g., transportation, agriculture, energy, water, and natural resource management) and public safety (e.g., hazard warnings). These data streams form the foundation for critical scientific research to improve fundamental understanding of the Earth system and its changing climate. They provide accurate forecasts, surveys, and

[16] For the purposes of this National Plan, a commitment to maintain observations for seven years or more is considered to be the minimum threshold necessary for provision of long-term services and research in the public interest. Most experimental observation programs are not planned to exceed seven years.

records that support U.S. scientific, economic, and commercial interests and, as such, are essential to the maintenance of national and economic security.

Sustained observations for public services are subdivided into two tiers, described below.

3.2.1.1. Tier 1

Based on results of the EOA, the following measurement groups support a majority of the societal themes.[17] These measurement groups represent the highest priority measurements in the category of sustained observations for public services. They are listed below in priority order.

1. Weather and seasonal climate monitoring and prediction: Observations in this measurement group characterize phenomena such as precipitation, storms, wind, floods, sea state, drought, wildfires, ice, air quality (including ozone), and weather risks to human health and transportation. They also contribute to short-term climate forecasts. These observations derive from next-generation radar on fixed and mobile platforms; atmospheric sounding from space and airborne platforms, oceanic measurements, and spectral and radiometric imaging of the Earth surface.

2. Dynamic land-surface monitoring and characterization: Observations in this measurement group support food and water security, water availability and quality, fire detection and suppression, human health, forestry, soil characterization (including soil moisture), hazards mapping and response, and natural-resource management. They particularly derive from multispectral and hyperspectral imaging from space and airborne platforms, forest inventory, and soil data collection.

3. Elevation and geo-location: Observations in this measurement group support food and water security, hazard and risk mapping, and natural-resource management. These observations particularly include topography and bathymetry, surface modeling, hydrologic data, and ecosystems-related data as derived from radar and laser sensors on satellite-based, airborne, and terrestrial platforms, as well as positioning, navigation, and timing satellites, such as those used for the Global Positioning System (GPS).

4. Water level and flow: Observations in this measurement group support coastal inundation and inland flooding, water availability, hydropower management, transportation, human health, water equivalent of snow, and tsunami hazard preparedness. They particularly derive from coastal and inland water level and flow measurements, seafloor topography, and ocean topography from satellite altimetry.

[17] These measurement categories were derived by reviewing the primary purpose of the 15 highest impact systems identified by the EOA across all SBAs. They are designated as Tier 1 systems in this National Plan. The examples of questions and phenomena supported by each measurement group are meant to be illustrative and do not represent the fullest range of possible uses for these measurements. A list of systems supporting Tier 1 measurements can be found in Table 1 in Annex I.

3.2.1.2. Tier 2

The following measurement groups are identified based on the remaining high-impact observing systems identified in the EOA.[18] These measurement classes are of next-highest priority and importance in the category of sustained observations for public services.[19] They are listed here in alphabetical order.

- Ecosystem and biodiversity resource surveys for terrestrial, freshwater, and marine ecosystems, including fisheries and wildlife management
- Environmental-quality monitoring, specifically disease-vector surveillance, water quality, and air quality associated with changes in atmospheric composition, including particulate matter and short-lived climate pollutants
- Geo-hazard monitoring for earthquakes, volcanoes, landslides, regional and local subsidence (e.g., sinkholes), inundation, and tsunamis
- Space-weather monitoring of geomagnetic storms, sunspots, solar flares, associated x-ray and ultraviolet emissions, solar wind (including coronal mass ejection), solar energetic particles, traveling ionosphere disturbances, and associated changes of the Earth's geomagnetic field and ionosphere for their impact on human activities

While the EOA provided higher overall scores to those systems that were identified as impacting more than one SBA, some of these systems contribute critically or are essential to key objectives in one or more SBAs. Some Tier 2 systems are critical in that they are the only observing systems available for a particular objective, so that objective could not be achieved without them.

3.2.2. Sustained Observations for Earth-System Research in the Public Interest

The public interest also requires sustained observations for understanding how and why the Earth system, including the Earth's climate, is changing. These observations are those measurements supporting continuous data streams or routinely generated data products that are needed for basic and applied research to advance human knowledge (climate-change research, solid-Earth research, meteorological research, ocean and water-cycle research, and space-weather research), to improve public services, and to support public and general education. These observations often require multi-year data collection and maintenance within a specific sampling frame (e.g., measurements taken at a specific location at a given interval). The purpose of such sustained observations is often long-term research, but the data collected often have immediate benefit for society and are frequently integrated into sustained services.

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[18] The measurement categories in Tier 2 were derived by analyzing the primary purpose of the observing systems not covered in Tier 1. Tier 2 includes the remaining high-impact systems identified in the EOA across all SBAs, and also includes additional special-purpose systems designated as high impact to specific individual SBAs. A list of systems supporting Tier 2 measurements can be found in Table 2 in Annex I.

[19] The tiers prioritize measurements, not the SBAs that the measurements support (e.g., understanding geo-hazards is not ranked below understanding weather hazards, but weather hazard measurements support a wider range of uses than geo-hazard measurements).

The following measurement categories, presented in alphabetical order, were identified for sustained research observations.[20]

- Atmospheric state, including measurements of temperature, pressure, humidity, wind, and ozone at the accuracy required for long-term climate research, and, as appropriate, to improve short- and medium-range weather forecasting;
- Cryosphere, including measurements of ice sheets, glaciers, permafrost, snow, and sea ice extent and thickness;
- Earth's energy budget, including total solar irradiance and Earth's radiation budget, and the reflectance and scattering properties of clouds, aerosols, and greenhouse gases, specifically for understanding Earth's sensitivity to climate change;
- Extremes, including specific and routine observations for the study of extreme temperatures, drought, precipitation, and wind;
- Geo-hazard research, including monitoring land-surface deformation to better understand regional and local disaster potential and effects, and the monitoring of phenomena that precede natural disasters, such as seismic, stress, strain, and geochemical and temperature changes;
- Greenhouse gas emissions and concentrations, including understanding sources and sinks of greenhouse gases, as well as changes in long-lived greenhouse gas and short-lived climate-pollutant concentrations over time;
- Integrated geophysical and biosphere characterization (terrestrial, freshwater, and marine), including long-term dynamics to understand ecosystem change and biogeochemical processes, particularly the carbon cycle;
- Ocean state, including observations of sea levels, temperature, salinity, pH, alkalinity, currents and characteristics of marine ecosystems;
- Space weather, including long-term understanding of the Earth-Sun relationship, solar dynamics, and the drivers of space-weather impacts at the Earth's surface, such as coupling between space weather and geomagnetic storms; and,
- Water cycle, including the analysis of droughts, floods, and water availability (precipitation, soil moisture, snow-water equivalent, evapotranspiration, groundwater, surface water, and runoff).

3.3. Experimental Observations

Experimental observations are defined as measurements planned for limited durations, generally seven years or less, that Federal agencies are committed to making for limited research and development purposes. These observations may be taken for a variety of purposes: to advance human knowledge

[20] The 2012 EOA included climate and related global change research needs as an SBA, but did not systematically prioritize research observations (see Footnote 13). Therefore, for the purposes of the National Plan, these measurement categories have been identified but not prioritized. Future assessments will address the question of priorities for sustained research in consultation with external stakeholders, including the National Academies, as appropriate.

through basic and applied research, to explore technical innovation, or to improve public services. These include first-of-their-kind observations, technology innovation and infusion (e.g., new methods, proofs of concept, and evolving observation platforms such as small satellites, microbuses, unmanned aerial vehicles, automated mobile and distributed sensor networks, and handheld devices), targeted activities (e.g., field campaigns, process studies, model validations, and design studies), and experiments for system improvements (e.g., risk reduction and upgrades).

The advancement of experimental scientific research on the Earth's fundamental processes is central to human progress, applicable to improvements in current and future service capabilities, and essential for achievement of other national Earth science objectives. Therefore, the Federal Government will pursue experimental and first-of-their-kind Earth observations to advance human knowledge, explore technical innovation, and improve services.

Innovation is an essential component in developing a robust portfolio of experimental observation systems. Evolving observation platforms offer the potential to make Earth observations more efficient, accurate, or economical over the National Plan's three-year timeframe. The infusion of new technologies requires investments in new sensors, materials, techniques, satellite architectures, and so forth, supported by research and development funding and combined with new scientific research with the objective of developing more efficient or higher quality observations. Experimental measurements drive innovation for research, form the basis of planned improvements in service-driven observations, and advance human knowledge and understanding.

Within this measurement category, the large-scale Earth science research programs of the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the United States Geological Survey (USGS), the Department of Energy (DOE), the United States Department of Agriculture (USDA), the Department of Transportation (DOT), and other agencies will continue setting priorities and advancing innovation in Earth observation by selecting and funding experimental observations.[21]

[21] Agency processes will include consultation with external stakeholders, such as the National Academies, as appropriate.

4. Priorities and Supporting Actions for Civil Earth Observations

Federal agencies will work with the Executive Office of the President and Congress to consider the following priorities and supporting actions. All priorities and activities outlined are to be conducted when feasible and within approved agency budgets.

4.1. Priorities

The most important principle governing the Nation's civil Earth observing systems is that the overall set of observations must yield a balanced portfolio across both sustained and experimental observation. This National Plan provides guidance in setting priorities for the construction of this balanced portfolio. In the balanced framework, no one category, tier, or observation automatically supersedes or supplants all others. Agencies, in consultation with the Executive Office of the President and Congress on these priorities, have discretion to deviate from this National Plan's rankings when necessary. In recognition of this, the National Plan accommodates this flexibility while meeting the Nation's overall civil Earth observation priorities and objectives.

The framework allows for, and recognizes the importance of, planned improvements to observing systems to maintain data of sufficient quality, while the Nation also seeks to improve observation techniques and the effectiveness and efficiency of Earth observations collection, dissemination, and use.

The priorities are listed in ranked order and are elaborated on in the subsections that follow.

1. Continuity of sustained observations for public services. Prioritize system investments to ensure continuity of public services.
2. Continuity of sustained observations for Earth system research. Establish and maintain programs to ensure data continuity for high-impact sustained research observations.
3. Continued investment in experimental observations. Continue to invest in research and development, incorporating technological advances to improve observations.
4. Planned improvements to sustained observation networks and surveys for all observation categories. Proceed with planned improvements to sustained observation systems.
5. Continuity of, and improvements to, a rigorous assessment and prioritization process. Initiate a national-level process for prioritizing sustained observations for both research and public services and for experimental observations, including a process for external advisory input and strategic balance.

4.1.1. Priority 1: Continuity of Sustained Observations for Public Services

Federal agencies engaged in Earth observations should work both individually and collectively to ensure the continuity of sustained observation systems essential in the maintenance of public safety, national and economic security interests, and programs supporting services critical to agency missions and scientific research. In particular, the President's FY 2015 budget provides support for Federal agencies to:

- Maintain the continuity of observations of current atmospheric conditions from satellites, terrestrial networks, and airborne and marine platforms to provide sufficient weather, hazard,

and air-quality forecasting and prediction; the efficient movement of commerce and goods; and the reanalysis of data sets for climate research and infrastructure planning.

- Maintain a sustained, space-based, land-imaging program while ensuring the continuity of 42 years of multispectral information and 36 years of thermal-infrared land-surface information from space, which are unique sources of terrestrial data for understanding land cover change.
- Maintain sufficient continuity of airborne remote-sensing capabilities for agricultural resource monitoring, as well as sustained observations from multiple platforms for forest inventories and soil surveys. Together these observations are a critical source of information on the management of Earth resources needed to sustain human life, agriculture, forestry, and economic activity.
- Ensure the continuity of the GPS satellite network and maintain related terrestrial reference-frame measurements. GPS is singularly important as the principal and irreplaceable reference for universal time and geo-reference measurements that underpin nearly all Earth observations.
- Establish and maintain a national program to standardize the regular collection of nationwide, high-resolution, three-dimensional data for surface modeling and volumetric analysis for multiple requirements (e.g., airborne light detection and ranging or LIDAR).
- Ensure continuity of terrestrial, marine, coastal, and inland water-level and flow measurements and maintain the continuity of ocean and seafloor topography measurements from satellite altimetry.
- Maintain continuity of space-weather observations, including sustained space-weather research measurements and ground observations, to provide definitive space weather forecasts, warnings, and alerts to the general public, industry, and government agencies.
- Maintain sufficient continuity of data from oceanic platforms (e.g., gliders and moored and drifting buoys).
- Maintain sufficient continuity of observations for ecosystem-resource surveys, environmental-quality measurements, and monitoring of solid-Earth hazards.

Current observing systems supporting this priority are shown in Annex I. To maintain continuity of these observations, follow-on and experimental observation systems will be developed within the timeframe of this National Plan.

4.1.2. Priority 2: Continuity of Sustained Observations for Earth System Research

Federal agencies will continue to collaborate with each other and with international partners to establish and maintain systems and networks specifically for sustained observations for Earth-system research.

Multiple agencies maintain extensive Earth-science programs that will continue to identify priorities for sustained observations for use in Earth-system research. The agency processes that direct these research programs will include consultation with external stakeholders, such as the National Academies, as appropriate. The President's FY 2015 budget provides specific support for agencies and their research programs to continue and strengthen their activities in support of this priority.

For example:

- NASA is extending measurements of groundwater, greenhouse gases, and aerosols from space-based platforms, in collaboration with international partners (see Section 6).
- NOAA is supporting a nationwide Federal network specifically designed and operated for the purpose of long-term climate monitoring. It primarily takes highly accurate measurements of air temperature, precipitation, soil temperature, moisture, and relative humidity for the purpose of detecting long-term climate change on a national scale. It also takes secondary or ancillary measurements of solar radiation, infrared temperature, and wind to assist in the calibration of the primary variables.
- NSF is supporting a federally funded, multi-site, national network designed to gather and synthesize data on the impacts of climate change, land-use change, and invasive species on natural resources and biodiversity. The network will combine site-based data with remotely sensed data and existing continental-scale data sets (e.g., satellite data) to provide a range of scaled data products that can be used to describe changes in the Nation's ecosystem over time.
- NSF has begun construction on a federally funded sensor network to measure the physical, chemical, geological, and biological variables in the ocean and on the seafloor. Knowledge of these variables improves detection and forecasting of environmental changes and their effects on biodiversity, coastal ecosystems, and climate.

Finally, multiple agencies are supporting the development of multi-site and multi-platform observing systems and networks that integrate observations on local to global scales to improve climate-change, biodiversity, and ecosystems research, among other areas.

4.1.3. Priority 3: Continued Investment in Experimental Observations

Experimental observations strengthen the Nation's Earth observation activities through the development and validation of new science, technologies, systems, techniques, and measurements to support both services and scientific research. The continual integration of experimental observations into the portfolio of Federal Earth-observing systems ensures that cutting-edge capabilities are maintained and measurements of increasing quality, accuracy, resolution, and density are provided. The President's FY 2015 budget provides funding for Federal agencies to act individually and in collaboration to support this priority.

4.1.4. Priority 4: Planned Improvements to Sustained Observation Networks and Surveys for All Observation Categories

Federal agencies will proceed with planned improvements to sustain observation systems, with special attention and priority given to include agencies' pre-planned improvements and service-life extension programs.

4.1.5. Priority 5: Continuity of, and Improvements to, a Rigorous Assessment and Prioritization Process

Federal agencies will collaborate with external stakeholders to continue and improve the assessment process initiated by the National Strategy. To this end, the newly re-chartered United States Group on Earth Observations (USGEO) Subcommittee of the NSTC's CENRS will oversee the EOA process on three-

year cycles, with the next EOA beginning in 2014. The next EOA will also seek additional insight with regard to research priorities and future needs.

4.2. Supporting Actions

The supporting actions required to meet the foregoing priorities are listed below in priority order and elaborated on in the subsections that follow.

1. Coordinate and integrate observations. Coordinate observing and integrate separate observations from multiple platforms, as appropriate, to include federated data sharing standards, ontologies, and user-adopted conventions.

2. Improve data access, management, and interoperability. Improve data discovery, access, and use of Earth observations by making them interoperable, providing open access to them, and presenting them in a machine-readable form for end user applications and services.

3. Increase efficiency and cost savings. Increase efficiency and cost savings of observation systems, by exploring tradeoffs among cost, capabilities, and risk and, as appropriate, reevaluating program overhead and management structures.

4. Improve observation density and sampling. Where appropriate and cost-effective, upgrade observing systems and widen their data dissemination to improve Earth-observation capabilities and reduce gaps in coverage.

5. Maintain and support infrastructure. Maintain necessary infrastructure to operate, manage, house, transport, deploy, modify, and support needed observing systems.

6. Explore commercial solutions. Improve entry points for exploiting cost-effective commercial solutions for the provision of Earth observations to encourage private-sector innovation and services while preserving the public-good nature of Earth observations.

7. Maintain and strengthen international collaboration. Maintain and strengthen international collaboration and data sharing.

8. Engage in stakeholder-driven data innovation. Engage with the private sector and the general public to encourage innovations for collection, exploitation, and wider use of Earth observations based on improved availability of open data, including new applications, new services, citizen science, and crowdsourcing.

4.2.1. Action 1: Coordinate and Integrate Observations

Sustained and experimental observations serve both services and research needs. Many near-term service benefits flow from research observations. Similarly, research is advanced through the data collected by service-driven observations that are archived, disseminated, and reused beyond the immediate user community. Agencies will examine improved methods for integrating sustained and experimental observations, and will explore collaboration to:

- Develop integrated Earth-observation requirements, recognizing unique requirements as appropriate.

- Advance algorithm development for integrating Earth observations from multiple sources, including improved capacity to integrate data from multiple spatial scales and reference models.
- Develop specific, coordinated observing systems and programs to meet integrated requirements; in particular, explore increased airborne, terrestrial, and marine data-collection coverage, coordinated with planned new satellite-observation systems.
- Enhance systematic strategies that can be used for calibration and quality assurance of all observation systems, whether airborne, terrestrial, or marine and satellite based, and develop standardized methods for collection of automated sensor-derived and human-acquired measurements.
- Consolidate, as appropriate, existing networks and mapping through interagency agreements that ensure interoperability, common measurement standards, and meaningful leveraging of resources. Examples of this approach include:
    - Bringing current coastal in situ systems together into a single, federated, coastal observing system under an optimized plan for the U.S. Integrated Ocean Observing System (IOOS®) and
    - Consolidating various land, coastal, and ocean ecosystem mapping projects into a national ecosystem map.
- Consolidate GPS surface-monitoring stations by reducing the number of stations where feasible without reducing coverage. Examples of GPS station networks include those used:
    - Through NSF for crustal motion detection,
    - By USGS for earthquake and volcano-hazard monitoring and early warning, and
    - By NOAA for tropospheric sounding activities.
- Continue development and operation of multi-platform observing systems that combine space, air, land, or ocean measurements to provide cost-effective, integrated analysis of Earth science phenomena.
- Coordinate efficient spectrum allocation and use for observing systems to enable the transmission of large amounts of data, particularly from Earth observing satellites.

4.2.2. Action 2: Improve Data Access, Management, and Interoperability

Realizing the full benefit of the nation's Earth observation investments requires more than the effective deployment of sensors and surveys. Observation data streams and their metadata generally feed machine-to-machine data processors that analyze, automate, integrate, display, and provide decision support tools to make use of large volumes of base data. By improving the management and preservation of Earth-observation data, Federal agencies help to ensure that both anticipated and unanticipated users can find, obtain, evaluate, understand, compare, and use legacy data in new ways.

Under this supporting action, Federal agencies will strengthen their individual efforts and collaborations to improve data discovery, access, archives, and use of Earth observations by making them interoperable, open, subject to shared generic message exchange patterns (e.g., publication/subscription), and machine-

readable.[22] To this end, Federal agencies will support development of a comprehensive data-management framework as an integral element of Earth-observation activities to improve access to, and use of, Earth observations by new and potential users. To accelerate the implementation of this framework, the President's FY 2014 and FY 2015 budgets invest in the Big Earth Data Initiative (BEDI) for standardizing and optimizing the collection, management, and delivery of Federal civil Earth-observation data.[23] BEDI also builds upon data-management work already occurring at the agencies.

Federal agencies will collaborate to do the following:

- Promote implementation of end-to-end life-cycle data management, including data-management principles, guidance, and data policy; life-cycle data-management approaches; architectural considerations; standardization; data evaluation; and data-telecommunication efficiency and innovation.

- Encourage the development and use of uniform methodologies and practices across Federal agencies for common services in the handling of Earth-observation data to increase interoperability through improved metadata standardization, filter, and subset services based on user needs, federated user management efforts, and robust standards for multi-use observation systems like LIDAR that are used across various Federal and State agencies.

- Maximize the likelihood that Earth observations are made known, made available, and disseminated to users in a timely and useable manner.

- Continue support for data-clearinghouse mechanisms that emphasize metadata cataloging (such as Data.gov) and advocate support for developing "big data" initiatives and common support services that aim to improve the discoverability, accessibility, usability for intended purpose, and re-purposing of the vast amounts of data already available.

- Support the further development of forecast models, sensor integration, display applications, signal-processing algorithms, and other data-collection and management techniques.

- Work within current, or support the development of new, communities of practice focused on data integration and cross-program coordination to address:
    - Community-based data standards;
    - Web services;
    - Application development;
    - Design of interoperable data systems based on technical standards;
    - Reduction of uncoordinated and duplicative web portals;

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[22] These efforts are in accordance with existing policy guidance on open data, including Executive Order No. 13642, "Making Open and Machine Readable the New Default for Government Information," and Office of Management and Budget (OMB) Memorandum M-13-13, "Open Data Policy—Managing Information as an Asset," both dated May 9, 2013.

[23] BEDI follows the life-cycle data-management principles articulated in the National Strategy and is designed to help Earth-science agencies comply more fully Executive Order No. 13642.

- Development of standardized data products; and
- Use of cloud-based infrastructure, platforms, and services for efficient data storage and virtual resource sharing.

- Create frameworks, platforms, and systems to integrate data obtained from multiple observations that measure common phenomena.
- Consider improving interoperability between Earth observation data and relevant data sets that are not based on Earth observations (e.g. census data) to support agency objectives.

4.2.3. Action 3: Increase Efficiency and Cost Savings

Federal agencies shall increase efficiency and cost savings in observation systems by exploring tradeoffs among cost, capabilities, and risk and, as appropriate, evaluating program-management structures and overhead. Specifically, agencies will take steps as follows:

- Increase efficiency.
  - Develop specific processes for regular evaluation of in situ airborne, terrestrial, marine, and satellite-based observation systems, both mobile and fixed. These evaluations should be used to guide the consolidation, relocation, expansion, or reduction of sites, instruments, or measurements when such actions offer improved efficiencies or cost-savings while maintaining data quality.
  - Evaluate commercial and foreign satellites and observation networks for their potential value in augmenting the U.S. Government's Earth-observing capacity.
  - Explore possibilities for common ground systems and dissemination mechanisms for satellite-derived information.
  - Consider refining satellite risk profiles for nonhuman spaceflight and streamlining review cycles to achieve cost savings and efficiencies, as appropriate.
  - Explore coordinated acquisition of sonar, radar, and LIDAR technology, as appropriate, to achieve efficiencies.
  - Conduct a study of radiosonde observations in proximity of aircraft soundings to achieve savings for the purpose of weather forecasting.
  - Increase coordination and cooperation in the use of vessels for oceanographic research and surveys of living marine resource.
  - Explore opportunities to leverage land- and ocean-observing platforms across programs and agencies.
  - Use modeling tools to supplement monitoring networks to fill in spatial and temporal gaps and potentially reduce monitoring requirements.

- Explore greater use of National Technical Means resources that could fulfill societal and research requirements through civilian tasking, unclassified product development, and public distribution.

- Improve coordination of sensor development and acquisition of imagery and data.
  - Improve interagency and external coordination in the organization of space-based sensor development and launch.
  - Develop a collaborative strategy among agencies and their primary users on climatology and continuity for ocean-color calibration, data processing, and product development through satellite platforms.
  - Coordinate airborne research efforts among interagency and international partners.
- Increase agencies' automation, remote configuration, and standby mechanisms.
  - Explore automation of surface-air-quality networks and connection with networks for other purposes to increase data utility across observation systems and programs.
  - Explore and, where cost-effective and appropriate, expand the use of airborne, terrestrial, or marine autonomously or remotely operated vehicles with sensor packages to provide more agility and to reduce costs in data acquisition.
  - Adopt automated measurement and data-collection techniques as legacy networks are modernized.
  - Adopt common software environments to allow for remote configuration updates of surface-observing platforms that will increase efficiency and reduce the cost of retrofitting individual sites.
  - Increase coordination of systems making compatible observations to enhance continuity of services and increase cost-savings. This might include optimizing the frequency and density of observations from systems in proximity to maximize coverage of specific phenomena (e.g., severe storms).
- Improve technical refresh for cost reduction.
  - Pursue improvements through value engineering and technical refresh activity to reduce life-cycle maintenance costs, eliminate proprietary restrictions, maintain replenishment sources when the original equipment manufacturer ceases support, and prevent information-technology obsolescence.

4.2.4. Action 4: Improve Observation Density and Sampling

Federal agencies will explore and pursue upgrading systems and techniques through improvements to spatial resolution, temporal cycle, sample density, and geographic coverage of observation networks to close coverage and performance gaps and improve calibration and validation of measurements. When feasible and within approved agency budgets, Federal agencies will, individually or collaboratively:

- Sustain and improve spatial, spectral, and temporal resolution.

- Collect and employ Earth-observation data, imagery, and reference measurements with higher temporal, spatial, and spectral resolution through more sustained observations and better reuse of related data, particularly for land imaging, boundary layer observations, air-quality measurements, natural hazards, hydrology, and severe-weather forecasting.

- Improve observation density and sampling through technical upgrades.
  - Upgrade receivers to take advantage of improved positioning, navigating, timing, and geodetic-observation capabilities as they are launched to provide better results and increased coverage.
  - Pursue the systematic integration and improvement of observing-system density and sampling with hydrodynamic and inundation models through use of uncertainty analyses to identify areas requiring new observations and better model performance.
  - Invest in advanced data calibration to improve real-time quality control, including field equipment, test kits, self-calibrating sensors, and other novel technologies.
  - Explore technologies that facilitate new measurements or greatly enhance current measurements, such as biotechnology for genetic user identification, portable laboratories and chips, and observer-centric mechanisms.
  - Equip and modify existing or planned platforms for sustained, multipurpose observations as appropriate.

- Create new data sets from forthcoming systems (e.g., air quality from geostationary environmental satellites and flight trajectory-oriented weather data from air transportation systems).

4.2.5. Action 5: Maintain and Support Infrastructure

Sustained Earth observations require the operation and maintenance of extensive physical, cyber, communications, and human infrastructure. Such infrastructure supports the maintenance, deployment, retrieval, replacement, and repair of Earth observation systems.[24] Agencies will identify, prioritize, and implement activities and document appropriate funding requirements for life-cycle operation, maintenance, and evolution of infrastructure required for them to sustain Earth-observation systems. As part of this process, agencies shall also consider cost-sharing for complementary and common infrastructure in support of their Earth-observation objectives.

Furthermore, agencies often conduct observations in remote areas and at great distances. The necessary supply-chain infrastructure to support these observations includes the Federal oceanographic and airborne research fleets and other systems. These fleets support sustained observations for both services

[24] Additionally, certain infrastructure can serve multiple purposes. For example, ships are able to place both researcher and technology at the site of the science and remain deployed "on effort" for extended periods of time.

and research across a broad spectrum of national needs.[25] Agencies should continue to maintain their relevant supply-chain infrastructure and document their related funding requirements.

4.2.6. Action 6: Explore Commercial Solutions

Federal agencies will identify and pursue cost-effective commercial solutions to encourage private-sector innovation while preserving the public-good nature of Earth observations. U.S. agencies will consider a variety of options for ownership, management, and utilization of Earth observation systems and data, including managed services (Government-Owned/Government-Operated, Government-Owned/ Contractor-Operated, or Contractor-Owned/Contractor-Operated), commercially hosted payloads, commercial launch, commercial data buys, and commercial data management. In developing such options, agencies will preserve the principles of full and open data sharing, competitive sourcing, and best value in return for public investments within legal and financial constraints.

4.2.7. Action 7: Maintain and Strengthen International Collaboration

The global nature of many Earth observations and the value of these observations to U.S. Government decision makers require U.S. agencies to carry out their missions through collaboration with foreign agencies, international organizations, and standards/coordination groups. Through international collaboration, U.S. agencies leverage foreign data and scientific expertise to improve their understanding of remote areas, such as the open ocean and polar regions, and to characterize global atmospheric, oceanic, and terrestrial phenomena. In addition, collaboration with international partners helps to minimize unnecessary redundancy in the collection of Earth observations, and ensures the effective use of limited resources. U.S. agencies also work closely with the Department of State and other agencies to provide associated scientific and technical support for U.S. foreign policy, security, economic, and environmental interests.

The concept of integrated Earth observations and open data management achieved international prominence in 2005 with the establishment of the intergovernmental Group on Earth Observations (GEO) and its agreement to support the development of a Global Earth Observation System of Systems (GEOSS).[26] This concept has been endorsed and is being implemented by over 90 governments, the European Commission, and more than 60 international organizations. The United States co-leads this international activity with China, the European Commission, and South Africa. GEOSS offers a comprehensive approach to observe all aspects of the Earth system and integrate the data gathered from these observations into timely and useful information for all sectors of society.

U.S. agencies engage in bilateral and multilateral collaboration with foreign partners and international organizations to obtain Earth-observation measurements necessary to improve U.S. scientific research, environmental monitoring, and related public- and private-sector decision making. Through their

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[25] The *Federal Oceanographic Fleet Status Report* is a an example of an effort to advance the efficient and effective operation of a Federal fleet, in part for the purpose of observations at the lowest possible life-cycle costs (http://www.whitehouse.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf).

[26] To further the objectives of GEOSS, U.S. agencies participate in various international organizations and coordination groups, including: the Intergovernmental Oceanographic Commission, United Nations Framework Convention on Climate Change, United Nations International Strategy for Disaster Reduction, World Meteorological Organization, and Committee on Earth Observation Satellites, among others.

international activities, U.S. agencies support full and open data exchange and collaborative research on matters of national and global importance.

In support of this action, Federal agencies will individually or collaboratively take the following actions:

- Maintain and expand bilateral and multilateral relationships as appropriate in support of national and international objectives.
- Improve access to non-U.S. satellite data, especially for domestic users.
- Explore the development of mechanisms for optimizing the collection, processing, and archiving of satellite data with the European Space Agency, the Japan Aerospace Exploration Agency, and other agencies to address specific SBAs (e.g., water).
- Continue U.S. involvement in global observation efforts and national activities that serve to further integrate national observing programs with internationally networked systems.
- Assess the potential for joint collection and processing of data from land-imaging systems to achieve savings through consolidation of image processing and to create a global source of timely, routinely available, ready-to-use measurements.
- Increase the level of international satellite collaboration to obtain specific measurements, following examples set by current collaboration in areas such as sea level, soil moisture, greenhouse gases, and ozone.

4.2.8. Action 8: Engage in Stakeholder-Driven Data Innovation

To improve the collection, exploitation, and use of Earth observations, Federal agencies will pursue private-sector innovations, public data crowdsourcing, and citizen science.[27] These three observation sources are all key components of a portfolio approach to Earth observations. Expected future technical developments throughout the National Plan's lifetime mean crowdsourcing, citizen science, and collection from individual mobile platforms will become increasingly important as they mature. Federal agencies will explore, support, and pursue efforts to enable stakeholder-driven data innovation from Earth observations.

Several initiatives have been launched to foster innovation in the exploitation and use of Earth observation data in the Climate SBA. Consistent with Executive Order No. 13642, "Making Open and Machine Readable the New Default for Government Information," and part of *The President's Climate Action Plan*, the Obama Administration launched a Climate Data Initiative in March 2014. This initiative

[27] Successful examples of these types of initiatives include USGS's "Did You Feel It?" program, which collects crowd-sourced data to better understand and measure earthquakes, and its Biodiversity Information Serving Our Nation (BISON) program, which aggregates species biodiversity data from a variety of sources, including museums, research studies, and citizen science programs. The President's Council of Advisors on Science and Technology has proposed the creation of an Ecoinformatics-based Open Resources and Machine Accessibility database called EcoINFORMA with the intention of making Federal data on environmental health widely accessible. Approximately 1,300 certified non-Federal, automated weather observing systems feed observation data into the Federal Aviation Administration's national automation systems. The non-Federal systems are owned and operated by various airport operating authorities including State, city, county, and local governments; municipalities; homeowners associations; and individual citizens.

leverages extensive Federal climate-relevant data to stimulate innovation and private-sector entrepreneurship in support of national climate-change preparedness. In conjunction with this initiative, Federal agencies will create a virtual toolkit that provides access to data-driven climate resilience tools, services, and best practices, including those developed through the Climate Data Initiative. Federal agencies should continue support for these and other initiatives encouraging innovative use of Earth observation data.

5. Civil Earth Observations from Airborne, Terrestrial, and Marine Platforms

Multiple Federal agencies manage the U.S. Government's airborne, terrestrial (including freshwater), and marine civil Earth-observation platforms and surveys, which gather remotely sensed, in situ, and human observations. The agencies that conduct or fund these observations include the Departments of Agriculture, Commerce, Defense, Energy, Interior, and Transportation; the Environmental Protection Agency (EPA); NASA; NSF; the Smithsonian Institution; and the U.S. Agency for International Development. In general these agencies, in accordance with their existing legal authorities, will continue to pursue the development of these platforms to observe and study the Earth system, with a focus on measurements described in this National Plan.

Airborne, terrestrial, and marine observations are vital to fulfilling Federal public-service obligations and research objectives across multiple SBAs. They provide critical information at high degrees of resolution, density, and efficiency. In addition to serving as primary sources of critical measurements and observations for public services and research across SBAs, these observations are essential to validate satellite-derived data products. Sustained airborne, terrestrial, and marine observations support the provision of public services and scientific research, while experimental observations in each of these categories both advance the state of science and improve the ability to monitor and measure the Earth system.

Continuous high-quality observations are critical for defining the current state of the Earth system; in particular, the constantly changing conditions of the atmosphere, hydrosphere, and biosphere. Observations from airborne, terrestrial, and marine platforms are required to accurately measure a number of Earth-system processes, including those related to biodiversity, groundwater, carbon sequestration, and the subsurface ocean. Long-time-series data derived from these observations contribute to more effective detection and diagnosis of climate change. Agencies should sustain the operations of established airborne, terrestrial, and marine observation platforms with ongoing attention to sufficient coverage and data quality.[28]

Recommendations from teams of SMEs for each SBA, as contained in the 2012 EOA, emphasized the need for sustained observations across SBAs to mitigate the significant risk of observation and data gaps, and, where possible and within agency approved budgets, the need for maintaining and improving the coverage and density of airborne, terrestrial, and marine observations, systems, and programs to preserve and enhance the long-term record.

The following categories highlight examples of high-impact airborne, terrestrial, and marine platforms and programs identified in the EOA. They provide sustained observations for public services, research, and experimental observations. Many of these observing systems are operated in partnership between Federal and non-Federal entities and many Federal agencies rely on these data for their operations. These

[28] For climate monitoring and research, agencies may refer to guidance provided by the Global Climate Observing System (GCOS). GCOS has identified 50 Essential Climate Variables (ECVs), which are required for systematic monitoring of, and research on, the Earth's changing climate. Fundamental Climate Data Records derived from airborne, terrestrial (including freshwater), marine and satellite-based observing systems are needed to address ECV information needs.

observations are grouped by platform and are presented in alphabetical order within each category (sustained and experimental).

5.1. Sustained Airborne, Terrestrial, and Marine Observations for Public Services and Research

5.1.1. Airborne Observations for Public Services and Research

The following examples of high-impact airborne platforms and programs identified in the EOA are presented alphabetically.

- *Airborne light detection and ranging (LIDAR):* Airborne observations used to create very high-resolution maps and elevation data sets, among other applications, are a high-impact category of observations conducted by multiple Federal and State agencies, commercial providers, and international partners. The 2012 EOA contained multiple recommendations from SME teams for sustained, expanded airborne three-dimensional measurements, which would benefit multiple SBAs. These measurements would significantly enhance high-resolution digital elevation models and shoreline mapping to improve services in the Disasters and Ocean and Coastal Resources and Ecosystems SBAs.

- *Airborne meteorological data collection and reporting:* Aircraft-based meteorological observations support improved weather forecasting, particularly for upper-air winds and severe weather. Real-time automated position and weather reports are used in predictive weather models on a daily basis. These measurements have an impact on eight SBAs, with "highest" impact on the Weather SBA.

- *Digital orthophotography*: Aircraft-based digital orthophotography provides imagery of the continental United States during agricultural growing and non-growing seasons. These measurements have an impact on nine SBAs, with "very high" or "highest" impact in the Agriculture and Forestry, Biodiversity, and Ecosystems SBAs. Agriculture SMEs recommended increasing the consistency of this imagery collection and integrating it with other relevant observations.

- *Radiosonde observations:* Radiosondes collect information on atmospheric temperature, pressure, and humidity using an instrument suspended from a balloon. The Federal Government has conducted upper air observations with radiosondes since the 1930s and currently uses radiosonde data in weather-prediction models; local severe storm, aviation, and marine forecasts; air-pollution models; satellite-data verification; and analysis of climate variability and change. Radiosonde observations impact nine SBAs, with "very high" impact in the Transportation SBA and "high" in Weather SBA.

5.1.2. Terrestrial (Including Freshwater) Observations for Public Services and Research

The following examples of high-impact terrestrial platforms and programs identified in the EOA are presented alphabetically.

- *Ground-based Weather Radars*: A national ground-based network of weather radars supports weather forecasting and warning services. These systems detect precipitation and wind and

contribute to severe-weather and flash-flood warnings, air-traffic safety, flow control for air traffic, resource protection at military bases, and management of water, agriculture, forests, and snow removal. The network impacts nine SBAs, with "highest" impact in the Transportation SBA and "very high" impact in the Weather and Energy and Mineral Resources SBAs.

- *Soil Observations:* A nationwide partnership of Federal, regional, State, and local agencies, along with private entities and institutions, cooperatively investigates, inventories, documents, classifies, interprets, disseminates, and publishes information about soils of the United States and its territories. These activities are carried out at national, regional, and State levels. This information has a "high" impact in the Agriculture and Forestry, Biodiversity, Ecosystems, Human Health, and Water Resources SBAs.

- *Stream Gage Network:* A nationwide network of stream gages operated by Federal, State, and local agencies provides stream flow monitoring and measurement and hydrological observations. These observations provide critical support to stream-flow forecasts, river-basin outflow forecasts, drought forecasts, water-quality measurements, and sentinel watershed monitoring. The network impacts ten SBAs, with "very high" impact in the Water Resources and Transportation SBAs.

5.1.3. Marine Observations for Public Services and Research

The following examples of high-impact marine platforms and programs identified in the EOA are presented alphabetically.

- *High-Frequency Coastal Radar Network:* An integrated network of high-frequency coastal radars, that is operated by Federal and institutional partners and provides measurements of surface currents over wide geographical areas, supporting the Transportation SBA.

- *Oceanic Buoys and Coastal Networks:* Networks of marine-based data buoys (moored, profiling, and drifting) and coastal stations that measure atmospheric and oceanographic variables such as wind speed, direction, and gust; barometric pressure; air temperature; sea surface temperature; wave height and periodicity; and ocean acidification, nutrients, and dissolved oxygen. The observations from moored buoys and coastal stations are transmitted in near real-time via satellites or communication pathways to a ground receiving facility. Buoy and coastal-station observation data are used to support marine warnings and advisories and the movement of ships in and out of port and to calibrate hurricane wind speed aircraft measurements and satellite sea surface temperature, wind, and wave observations; for directional wave measurement to study coastal erosion; and for detection of algal blooms and pathogens. These buoys impact multiple SBAs, with "high" impact in the Weather, Ocean and Coastal Resources and Ecosystems, and Transportation SBAs.

- *Survey vessels:* Survey vessels are important observation platforms for the Ocean and Coastal Resources SBA. Large-ship assets and a fleet of smaller and charter vessels form the foundation for sampling and sensing the marine ecosystems along the coast, on the continental shelves, and in the open ocean. They support the collection of living marine resources for fishery assessment and the observation and tagging of protected resources to more fully characterize the ocean system. The data, information, and results from these surveys are used widely.

5.1.4. Multi-platform Observations for Public Services and Research

The following examples of high-impact multi-platform systems and programs identified in the EOA are presented alphabetically.

- *Aquatic Resource Surveys:* The Federal Government conducts aquatic-resource surveys in partnership with State and tribal governments. These projects monitor and catalog the Nation's aquatic resources through probability-based surveys that provide nationally consistent scientific assessments of lakes, rivers, streams, coastal waters, and wetlands. These surveys track the status and vitality of aquatic resources and can be used to monitor changes in condition over time. They measure biological quality, chemical stressors, habitat stressors, and human-health indicators. These surveys have a "very high" impact in the Ecosystems SBA.

- *Forest Observations*: The Federal Government has collected and analyzed forest data for decades. Today's activities include an annual forest inventory that consists of forest-health indicators, timber-product output studies, woodland owner surveys, and a National Assessment produced every five years. These activities rely on aerial photographs, digital orthoimagery, satellite imagery, field samples, surveys, and utilization studies to project forest status, health, and coverage and assess forest-management policies and practices. They impact four SBAs, with "highest" impact in the Agriculture and Forestry and Ecosystems SBAs.

- *Water-Level Observations:* These observations monitor, measure, and assess the impact of changing water levels for government and commercial navigation, recreation, and coastal-ecosystem management. Sensors are deployed across the Nation's lakes (roughly 25% in the Great Lakes), estuaries, and ocean coastal zones. They provide the national standards for tide-and water-level reference datums used for nautical charting, coastal engineering, international treaty regulation, and boundary determination. This network of sensors impacts five SBAs, with "highest" impact in the Reference Measurements SBA and "very high" impact in the Transportation SBA. In the 2012 EOA, multiple SME teams recommended additional support to improve services and research in the Disasters, Human Health, and Transportation SBAs, and the Reference Measurements societal theme.

5.2. Experimental Airborne, Terrestrial, and Marine Observations

Federal agencies routinely conduct experimental airborne, terrestrial, and marine observations to advance human knowledge through basic and applied research, to explore technical innovation, and to improve public services. Multiple SME teams involved in the 2012 EOA recommended, when feasible and within approved agency budgets, pursuing experimental research and testing to develop additional airborne capabilities for technologies such as LIDAR. Specific recommendations included developing three-dimensional imaging for ecosystem structure, improving instruments to enable photon counting, and improving near-coastal topographic/bathymetric measurements. Multiple SME teams recommended the use of unmanned vehicles to expand coverage and efficiency of observations in areas such as land-surface, coastal, and ocean monitoring and research; species surveys; and hurricane forecasting. Several SME teams recommended additional research to improve radar system scanning rates and coverage. Finally, multiple SME teams recommended continued support for ecological observations to support fundamental research and to test emerging observation technologies and experimental techniques.

6. Agency Roles and Responsibilities for Civil Earth Observations from Space

The NASA Administrator, the Secretary of Commerce through the NOAA Administrator, and the Secretary of the Interior through the USGS Director, have responsibility for managing the U.S. Government's space-based civil Earth-observation systems. Following guidance provided by the 2010 National Space Policy[29] and in accordance with existing legal authorities, these agencies will continue the development of satellites to observe and study the Earth system, with a focus on measurements and observation programs necessary for weather forecasting, environmental monitoring, disaster-risk reduction, water-resources assessment, and climate-change research.

Observations from space are also vital to fulfilling Federal objectives across multiple SBAs. They provide critical information on atmospheric, oceanic, and terrestrial phenomena at local, regional, continental, and global scales. These observations often cover broad areas, over long periods, and with frequent revisit rates. Space provides a unique vantage point for observations, and many global data sets collected from space cannot be easily replaced by other means. Continuous high-quality observations from space are also essential for an adequate understanding of the state of the Earth system, especially on a global basis. Space-based observations support the provision of sustained public services and scientific research, and they provide a vehicle for experimental studies that advance the state of science and improve the ability to monitor and measure the Earth system.[30]

Specifically, Federal agencies will conduct sustained satellite civil Earth observations as described below. All launch dates are contingent on congressional funding of the President's annual budget requests.

6.1. Sustained Satellite Observations for Public Services

The following observations from space-based systems are important to the provision of public services. While some agencies conduct these observations to support public-service products, other agencies may also conduct research efforts in these same areas. These observations are presented alphabetically.

6.1.1. Air Quality and Ozone

The Secretary of Commerce, through the NOAA Administrator, will provide air-quality data from the suite of instruments on the Joint Polar Satellite System (JPSS) satellites, the Suomi National Polar-orbiting Partnership (S-NPP) satellite, and the Geostationary Operational Environmental Satellite (GOES) series of satellites, which measure aerosols, trace gases, and meteorological data. The Secretary of Commerce, through the NOAA Administrator, will also provide statutorily mandated sustained observations of total column ozone through the Ozone Mapping and Profiler Suite (OMPS) Nadir sensor currently on the S-NPP satellite and the JPSS-1 and -2 satellites. The NASA Administrator will study options and explore working with the Secretary of Commerce, through the NOAA Administrator, to continue ozone-profile measurements currently being made by the OMPS Limb sensor on the S-NPP satellite.

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[29] *National Space Policy of the United States of America*, June 28, 2010, pp. 12–13, http://www.whitehouse.gov/the-press-office/fact-sheet-national-space-policy.

[30] Data from NASA programs are used to improve public services for air quality, ocean color, and space weather, for example.

6.1.2. Land-Imaging

The NASA Administrator, together with the Secretary of the Interior through the Director of USGS, will implement a 25-year program of sustained land-imaging for routine monitoring of land-cover characteristics, naturally occurring and human-induced land-cover change, and water resources, among other uses.[31]

They will also ensure that future land-imaging data will be fully compatible with the 42-year record of Landsat observations. The NASA Administrator will be responsible for satellite development, launch, and commissioning, and the Secretary of the Interior, through the USGS Director, will be responsible for representing users' requirements; development and operation of the ground system; operational control of satellites once on orbit; and processing, archiving, and distributing land-imaging data and routine information products. The NASA Administrator and the Secretary of the Interior, through the USGS Director, will continue to collaborate to address common needs for data continuity and new technology deployment.

6.1.3. Ocean-Color Observations

The Secretary of Commerce, through the NOAA Administrator and in collaboration with the NASA Administrator, will conduct sustained ocean-color observations for marine ecosystem monitoring. The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on the S-NPP satellite accomplishes this monitoring, which will be continued with the launches of the JPSS satellite series.[32]

6.1.4. Ocean Surface and Water-Level Monitoring

The Secretary of Commerce, through the NOAA Administrator and in collaboration with the NASA Administrator and international partners, will conduct sustained observations for ocean surface and inland water-level monitoring for sea level, navigation, ocean and coastal products, and geophysical reference. The altimeter on the Jason series of satellites accomplishes this monitoring, a task that will be continued with the launch of Jason-3 scheduled in 2015.

The Secretary of Commerce, through the NOAA Administrator, will cooperate with interagency and international partners to provide active (e.g., C-band Synthetic Aperture Radar or SAR) and passive (e.g., high-resolution microwave) data for ocean-surface monitoring. The primary objectives of this monitoring will be to support safety of navigation through routine generation of ice charts and analyses, to support environmental assessment through detection and analysis of pollution (e.g., oil spills) and detection and analysis of coastal change and ocean fronts. For these applications, the Secretary of Commerce, through the NOAA Administrator, will seek to use data from the U.S. Defense Meteorological Satellite Program Special Sensor Microwave Imager instrument series, the Canadian Space Agency Radarsat-2 and Radarsat Constellation satellites, and the European Space Agency Sentinel-1 series of C-band SAR instruments.

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[31] A robust land-imaging program requires data to supplement optical imagery. Non-optical sensing capabilities such as radar, LIDAR, and gravity measurements are needed to assess natural and anthropogenic hazards and to measure changes to topography, biomass, ecosystem flux, soil moisture, coastal and inland land subsidence, surface water, groundwater, and glaciers.

[32] NOAA will also seek to use data from the European Space Agency Sentinel-3 series of SAR instruments, launching in 2015.

6.1.5. Ocean-Surface Vector Winds

The Secretary of Commerce, through the NOAA Administrator and in collaboration with the NASA Administrator, will continue to cooperate with foreign partners to obtain scatterometry data for the measurement of near-ocean-surface wind speed and direction. These data sets can enhance modeling of the atmosphere, surface waves, and ocean circulation, with the potential to support a wide range of marine operations and enhance climate research and marine weather forecasting. The United States will obtain these data through continued U.S. access to data from the Advanced Scatterometer instrument on the European MetOp series of satellites and from the Oceansat-2 Scatterometer instrument on the Indian Space Research Organization satellites.

6.1.6. Space Weather Monitoring

The Secretary of Commerce, through the NOAA Administrator and in consultation with the NASA Administrator and interagency and international partners, will conduct sustained observations for space weather monitoring and prediction, which require constant operations. Specifically, the Secretary of Commerce, through the NOAA Administrator, will provide observations of solar wind (including coronal mass ejection), solar flares, and energetic particles, and will provide radio occultation and related measurements to forecast space weather events. The Secretary of Commerce, through the NOAA Administrator, will provide these measurements through the GOES series and the Deep Space Climate Observatory (DSCOVR) satellite (to be launched in 2015) and will study options and explore working with international and interagency partners to provide these measurements beyond the design life of the DSCOVR mission.

6.1.7. Weather, Hazards, and Seasonal/Inter-annual Climate Variability

The Secretary of Commerce, through the NOAA Administrator and in collaboration with the NASA Administrator and international partners, will provide sustained satellite observations for monitoring and predicting weather and related hazards, which require constant operations. These observations comprise atmospheric sounding and imaging of the Earth; space-based environmental data relay for weather; and other products critical to the protection of lives, property, air quality, and public health. The Secretary of Commerce, through the NOAA Administrator, will also process long time-series data from these observations for reanalysis and modeling to better understand seasonal to decadal climate trends.

The Secretary of Commerce, through the NOAA Administrator, will conduct these observations through the GOES series, the JPSS program (including S-NPP and future JPSS satellites), and the Polar-orbiting Operational Environmental Satellite (POES) series. Federal agencies will collaborate to launch the next satellite in the GOES series in 2016 and the first of the future JPSS satellites in 2017.

Both NOAA's GOES and JPSS programs will experience overlapping technology infusion and the use of next-generation launch systems during the next 10-year period. Therefore, the Secretary of Commerce, through the NOAA Administrator, will take steps to re-phase future development and operational life cycles of these two programs to reduce pressure from simultaneous budget peaks in both. The Secretary of Commerce, through the NOAA Administrator, will also seek to employ related program adjustments, as appropriate, to improve flexibility and efficiency as part of a portfolio-managed approach, maintain sustained observations in the most cost-effective manner, and achieve a robust architecture for observations.

The Secretary of Commerce, through the NOAA Administrator and in collaboration with interagency and international partners, will also continue to develop and acquire GPS radio-occultation measurements to enhance weather observation and prediction through the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) and COSMIC-2 missions.

6.2. Sustained Satellite Observations for Earth System Research

The NASA Administrator will conduct sustained satellite observations for research to advance the understanding of changes to the Earth system and related climate change. The Secretary of Commerce, through the NOAA Administrator and in collaboration with the NASA Administrator and other agencies, will also provide sustained observations for research on seasonal and inter-annual climate trends. Specific satellites will provide observations of the environmental phenomena described in the following subsections. These observations are presented alphabetically.

6.2.1. Aerosols and Trace Gases

In addition to the aerosols and trace gas data provided by NOAA, the NASA Administrator will provide long-term measurements of the vertical structure of aerosols, ozone, water vapor, and other important trace gases in the upper troposphere and stratosphere through the latest Stratospheric Aerosol and Gas Experiment (SAGE III) on the International Space Station (ISS). The NASA Administrator will launch SAGE-III on ISS in 2015, advancing the measurements provided by the previous Stratospheric Aerosol Measurement (SAM I and II), the SAGE I and II instruments, and the SAGE III Meteor-3M. Furthermore, the NASA Administrator will study options for continuing ozone-profile measurements planned for JPSS and explore collaboration with the Secretary of Commerce, through the NOAA Administrator, on OMPS measurements.

6.2.2. Atmospheric Carbon Dioxide

The NASA Administrator will provide global measurements of atmospheric carbon dioxide (CO_2) through the Orbital Carbon Observatory (OCO), launched in July 2014. OCO measurements will be combined with data from a ground-based network to provide information needed to better understand the processes that regulate atmospheric CO_2 and its role in the Earth's carbon cycle. Additionally, the NASA Administrator will explore using data from carbon dioxide monitoring missions planned by international partners.

6.2.3. Groundwater

The NASA Administrator will conduct precision measurements of the Earth's gravitational field that support groundwater measurements. Measurements taken through the Gravity Recovery and Climate Experiment (GRACE) help characterize the movement of underground water reservoirs and their seasonal variability.

The NASA Administrator will launch the GRACE follow-on in 2017, which will continue the measurement record established by the first GRACE launched in 2002. In addition, NASA and the Indian Space Research Organisation (ISRO) are cooperating to develop the NASA-ISRO Synthetic Aperture Radar (NI-SAR) mission, an L- and S-band radar satellite that will be able to measure land subsidence in relation to groundwater resources.

6.2.4. Net Energy Balance

To understand incoming and outgoing radiant energy of the Earth system, Federal agencies have collaborated to create a 30-year-plus record of total solar irradiance and a 10-year-plus record of clouds and the Earth's radiation balance. The Secretary of Commerce, through the NOAA Administrator, and the NASA Administrator will continue these measurements as follows:

- Radiation Budget: The Secretary of Commerce, through the NOAA Administrator, will launch a new Clouds and the Earth's Radiant Energy System (CERES) sensor on JPSS-1 in 2017, and the NASA Administrator will process the sensor's data. These observations will provide continuity for the series of measurements currently produced by S-NPP and NASA's Aqua and Terra satellites. Both the Secretary of Commerce, through the NOAA Administrator, and the NASA Administrator will explore options for a future Radiation Budget Instrument.

- Total Solar Irradiance: The Secretary of Commerce, through the NOAA Administrator, will complete and launch the Total Solar Irradiance Sensor (TSIS-1). The NASA Administrator will develop plans for continuing solar irradiance observations beyond the life cycle of TSIS-1. These programs will continue the data record currently produced by NASA's Solar Radiation and Climate Experiment (SORCE) and Active Cavity Radiometer Irradiance Monitor (ACRIMSAT) satellites, as well as the Total solar irradiance Calibration Transfer Experiment (TCTE), a joint program in which NOAA and NASA collaborated to include a Total Irradiance Measurement (TIM) sensor as a hosted payload on an Air Force STPSat-3 satellite launched in 2013.

6.3. Experimental Satellite Observations

In addition to the roles listed above, the NASA Administrator, in collaboration with other agencies, will conduct experimental observations of the Earth from space to advance human knowledge of the Earth as an integrated system. The NASA Administrator will accomplish these observations through the NASA Earth Systematic Missions and Pathfinder programs. The NASA Administrator will also continue its Venture Class program for innovative new research satellites. Through these programs, the NASA Administrator plans to launch experimental observations for the following measurements relevant to the understanding of climate and related global change (listed chronologically by actual or projected launch date):

- Global precipitation through the Global Precipitation Measurement (GPM) satellite, launched in February of 2014.

- Soil moisture through the Soil Moisture Active Passive (SMAP) satellite, to be launched in 2014.

- Cyclone generation through the Cyclone Global Navigation Satellite System (CYGNSS), to be launched in 2016.

- Ice-sheet mass balance, clouds and aerosols, and land elevation through the second Ice, Cloud, and land Elevation Satellite (ICESat-II), to be launched in 2017.

- Tropospheric pollution through the Tropospheric Emissions: Monitoring of Pollution (TEMPO) satellite, to be launched in 2019.

- Surface-water and ocean topography through the Surface Water Ocean Topography (SWOT) satellite, to be launched in 2020.

- Solid-Earth deformation, ice masses, and ecosystems through the NI-SAR satellite, to be jointly developed by NASA and ISRO.

In addition, the NASA Administrator will continue studying the feasibility of new satellite systems for observations of clouds and aerosols, land-surface characterization and deformation, hurricane formation, ecosystems classification, vegetation analysis, space-weather monitoring, and disaster-risk reduction, among others.

7. Summary Guidelines in Implementation and Coordination of the National Plan

Implementation and coordination of activities outlined in this National Plan will be conducted through Federal agencies' existing budgets, program planning, and NSTC-sponsored interagency processes. Implementation schedules, progress reviews, and funding profiles will be determined by Federal agencies in consultation with the Executive Office of the President.

The primary forum for interagency discussion and coordination of Earth observation, related data management, and related international issues is the USGEO Subcommittee of the NSTC. Within this forum, specialized working groups will facilitate triennial Earth observation assessments, enhanced data discoverability, accessibility, and usability initiatives, and U.S. participation in the intergovernmental GEO. Federal Earth observation agencies will designate appropriate representatives to the USGEO Subcommittee, and corresponding SMEs to its working groups as appropriate.

To maximize the utility of Earth observations to the widest range of internal and external stakeholders and inform Federal Earth-observation activities with valuable stakeholder perspectives, USGEO Subcommittee and Working Group representatives will consult as appropriate and exchange information and expertise with CENRS subcommittees and working groups.[33] Other NSTC entities that will benefit from coordination with USGEO include the NSTC Committee on Technology's Subcommittee on Network and Information Technology Research and Development and the NSTC Committee on Homeland and National Security's Topics of International Science and Technology Innovation Subcommittee.

OSTP, in consultation with the USGEO Subcommittee and CENRS member agencies, will review and update this National Plan on a three-year cycle. As part of this process, OSTP will solicit and consider the input of external stakeholders and the general public.

[33] These groups might include, but are not limited to, the Subcommittee on Global Change Research, the Subcommittee on Disaster Reduction, the Subcommittee on Ecological Services, the Interagency Arctic Research Policy Subcommittee, the Subcommittee on Water Availability and Quality, the Subcommittee on Air Quality Research, and the Subcommittee on Ocean Science and Technology.

Annex I: 2012 EOA Results

This annex provides results for the 145 high-impact observation systems identified from the 362 observation systems assessed by the 13 SBA teams of approximately 300 Federal subject-matter experts. These 145 observation systems are listed in two tiers in the tables below. Impact is indicated with respect to each of the 13 societal themes (12 SBAs and reference measurements), as described in Section 2.2.

Table 1: Tier 1 High-Impact Observation Systems (Ranked Order)

Observation System (Ranked Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
1. Global Positioning System (GPS) satellites	DOD/USAF													
2. Next Generation Weather Radar (NEXRAD)	DOC/NOAA								*					
3. Landsat satellite	DOI/USGS, NASA										*			
4. Geostationary Operational Environmental Satellite System (GOES-NOP)	DOC/NOAA			*		*								
5. National Agriculture Imagery Program (NAIP)	USDA/FSA													
6. Airborne LIDAR	DOC/NOAA, DOD/USACE, DOI/USGS, NSF													
7. Forest Inventory and Analysis (FIA)	USDA/USFS							*						

Impact:	**Contributes**	**Moderate**	**High**	**Very High**	**Highest**
	*				

Observation System (Ranked Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
8. Aircraft Meteorological Observations (e.g., MDCRS, AMDAR)	DOC/NOAA, Non-USG													
9. National Water Level Observation Network (NWLON)	DOC/NOAA											*		
10. Terra satellite	NASA										*			*
11. MetOp - Polar Orbiting Operational Meteorology (satellite, EUMETSAT)[a]	Non-USG					*				*				
12. Radiosonde Observations by National Weather Service (RAOBS)	DOC/NOAA					*			*					
13. USGS Stream Gage Network	DOI/USGS						*							
14. Suomi National Polar-orbiting Partnership (S-NPP) satellite[b]	NASA, NOAA													
15. Jason satellite	DOC/NOAA, NASA	*	*											

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Note: The EOA value chain began by identifying high-impact data sets and information products, and then observing systems that generate or contribute to those data sets and information products. As a result, the EOA captured the impact of certain non-USG sources of data, including from international, non-governmental, and commercial partners. Furthermore, the EOA results are derived from the findings of the SBA subject matter experts, and may not reflect all uses of well-known observing systems. In the table above, an asterisk indicates that the EOA scored this system as contributing to the SBA but not at a moderate or high level.

[a] Both the MetOp satellites and POES system are part of the constellation required to meet the key objectives in relevant SBAs.

[b] At the time of the EOA, S-NPP had only recently been launched and its impact on key objectives in relevant SBAs had yet to be fully realized.

Table 2: Tier 2 High-Impact Observation Systems (Alphabetical Order)

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Advanced Composition Explorer (ACE) satellite	NASA													
Advanced National Seismic System (ANSS)	DOI/USGS													
Aerial Observers - Aerial Detection Surveys (ADS)	DOC/NOAA, USDA/USFS													
Agricultural Attaché Reports	USDA/FAS													
Agricultural Economic Data	USDA													
Airborne Geophysical Measurements	DOI/USGS, EPA													
Airborne High-Resolution Optical Imagery	DOC/NOAA, DOD, NASA, USDA													
Airborne Hyperspectral Imagery	NASA				*									

Impact:	**Contributes**	**Moderate**	**High**	**Very High**	**Highest**
	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Airborne Interferometric Synthetic Aperture Radar (InSAR)	Non-USG						*							
Airborne Radar - U.S. Coast Guard	DHS/USCG													
Airport Surveillance Radar (ASR)	DOT/FAA													
American Academy of Allergy Asthma & Immunology National Allergy Bureau (AAAAI-NAB) pollen counts	Non-USG													
AmeriFlux Network	DOE													
Aqua satellite	NASA										*			
Argo Oceanographic Profilers	DOC/NOAA		*		*							*		
Atmospheric Integrated Research Monitoring Network (AIRMoN)	DOC/NOAA													

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Aura satellite	NASA						*							
Automated Surface Observing System (ASOS)	DOC/NOAA, DOT/FAA		*	*		*								
Automated Weather Observing System (AWOS)	DOT/FAA		*	*		*								
Autonomous Underwater Vehicles (AUVs) - temperature, salinity, and currents measurements	DOC/NOAA						*							
Breeding Bird Surveys (BBS)	DOI/FWS													
BLM Rapid Eco-regional Assessments (REA) & other federal/state agency/NGO Landscape Assessments (RA)	DOI/BLM													
Centers for Disease Control and Prevention (CDC) Surveillance	HHS/CDC				*									
Chartered Survey Vessels for Benthic Habitat observations	DOC/NOAA						*	*						

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Chartered Vessels for Fish Surveys	DOC/NOAA													
Clean Air Status and Trends Network (CASTNET)	EPA													
Coastal Buoys (National Data Buoy Center Buoys, IOOS)	DOC/NOAA						*					*		
Commercial Fishery Catch Monitoring	DOC/NOAA													
Commercial High-Resolution Satellite Imagery	Non-USG													
Commercial Radar Satellites (e.g., RadarSat, TerraSAR-X)	Non-USG													
Deep-ocean Assessment and Reporting of Tsunamis (DART) Buoys	DOC/NOAA													
Defense Meteorological Satellite Program (DMSP)	DOD/USAF								*		*			

Impact:	**Contributes**	**Moderate**	**High**	**Very High**	**Highest**
	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Direct Reports from Farmers (Crop Reports, FSA Form 578)	USDA/FSA													
Disaster Incident Reports	EPA, DHS/FEMA													
Disaster Monitoring Constellation (DMC) satellites (foreign)	Non-USG					*								
DOE Atmospheric Radiation Measurement (ARM) Climate Research Facility	DOE							*						
Drifting Buoy Network	DOC/NOAA		*				*	*				*		
Earth Observing Satellite - 1 (EO-1)	NASA													
EPA Emissions Source Testing/ Measurement Programs (EST/M)	EPA													
EPA Water Quality Samples	EPA				*									

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Farm Operator Surveys	USDA/NASS					*								
Farm Service Agency Reporting	USDA					*								
Fish and Wildlife Service Inventory and Monitoring (I&M) Program	DOI/FWS													
Fisheries Observers on Commercial Vessels	DOC/NOAA													
Global Avian Influenza Surveillance	HHS/CDC													
Global Biodiversity Information Facility Network (GBIF)	DOI/USGS	*												
Global Change Observation Mission - Water (GCOM-W) Advanced Microwave Scanning Radiometer 2 (AMSR2)	Non-USG													
Global Climate Observing System (GCOS) Upper Air Network (GUAN)	Non-USG					*					*			

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Global Lake Ecological Observatory Network (GLEON)	NSF													
Global Navigation Satellite System Meteorology (GNSS-Met)	DOC/NOAA			*				*			*	*		
Global Ocean Observing System (GOOS) Tropical Moorings (TAO/RAMA/PIRATA)	DOC/NOAA		*		*									
Global Sea Level Observing System (GLOSS) (international)	Non-USG										*			
Global Seismographic Network (GSN)	DOI/USGS, NSF													*
Gravity Field and Steady-State Ocean Circulation Explorer (GOCE)	Non-USG										*	*		
Gravity for the Redefinition of the American Vertical Datum (GRAV-D)	DOC/NOAA											*		
Gravity Recovery and Climate Experiment (GRACE) satellite	NASA												*	

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
High Frequency (HF) Coastal Radars	DOC/NOAA						*						*	
International Doppler Radar	Non-USG													
International Global Navigation Satellite Systems (GNSS)	Non-USG				*						*			
International Magnetometers	Non-USG													
Jet Propulsion Lab MODIS/ASTER airborne simulator (JPL MASTER)	NASA													
Lightning Data Buy	DOC/NOAA											*		
Long-Term Ecological & Agroecosystem Research Networks & International LTER (LTER/LTAR/ILTER)	NSF, USDA						*							
Low Level Windshear Alert System (LLWAS)	DOT/FAA													

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Meteosat satellite (EUMETSAT)	Non-USG		*	*				*	*					
Micro-Pulse LIDAR Network (MPLNET)	NASA						*							
Multifunctional Transport Satellite (MTSAT) Imager for Weather and Aviation Control (Japan)	Non-USG			*			*	*			*			
National Air Toxics and Trends Stations (NATTS)	EPA													
National Animal Health Surveillance System (NAHSS)	USDA/APHIS													
National Aquatic Resource Surveys (NARS)	EPA													
National Ballast Information Network	DHS/USCG													
National Cooperative Soil Survey	USDA/NRCS													

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

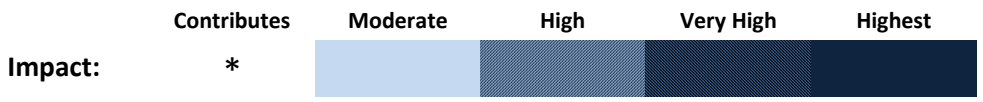
Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
National Park Service Inventory and Monitoring (I&M)	DOI/NPS													
National Phenology Network (NPN)	DOI/NPS, DOI/USGS, NSF													
National Weather Service (NWS) Cooperative Observer Program (COOP)	DOC/NOAA													
National Weather Service Skywarn Spotters	DOC/NOAA										*		*	
NOAA and Chartered Aircraft for Protected Species Surveys	DOC/NOAA													
NOAA Global Monitoring Division Observatories	DOC/NOAA													
NOAA Profiler Network	DOC/NOAA		*	*								*		
NOAA Recreational Fish Surveys	DOC/NOAA													

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
NOAA Ship and Chartered Ship for Coral Reef Field Surveys	DOC/NOAA													
NOAA Ships - Fish Surveys	DOC/NOAA													
NOAA Ships - Hydrographic Surveys	DOC/NOAA				*						*			
NOAA Ships - Protected Species Observations	DOC/NOAA													
Non-Federal Biological Surveys	Non-USG	*												
Ocean Reference Station Buoys	DOC/NOAA							*						
Physical Oceanographic Real-Time System (PORTS)	DOC/NOAA				*		*							
Pilot Reports (PIREPS)/Aircraft Reports (AIREPS)	DOT/FAA		*									*		

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Polar-orbiting Operational Environmental Satellite System (POES)[a]	DOC/NOAA		*											
Port Radars	DHS/USCG													
Portable Water Gages	DOC/NOAA, DOI/USGS										*			
Rain Gage Networks (state, local)	Non-USG				*						*			
Regional and State Mesonetworks	DOC/NOAA		*			*					*			
Road Weather Information Systems (RWIS)	DOT/FHWA													
Satellite Pour l'Observation de la Terre (SPOT) (France)	Non-USG				*			*						
Sentinel Animals (state and local)	Non-USG						*							



[a] Both MetOp satellites and POES system are part of the constellation required to meet the key objectives in relevant SBAs.

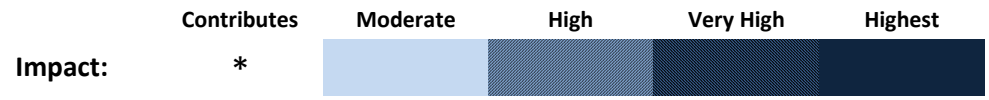
Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Shipboard Radars	DHS/USCG, DOC/NOAA, DOD/USN													
Ships of Opportunity Program (SOOP)	DOC/NOAA						*							
Small Boat Charters - Harmful Algal Bloom Water Sampling	DOC/NOAA													
Smithsonian Institution Global Earth Observatory (SIGEO)	SI													
SNOwpack TELemetry (SNOTEL)	USDA/NRCS						*							
Soil Climate Analysis Network (SCAN)	USDA/NRCS						*							
Soil Moisture and Ocean Salinity Mission (SMOS) satellite (ESA)	Non-USG													
Solar and Heliospheric Observatory (SOHO) satellite	NASA													

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Solar Dynamics Observatory (SDO) satellite	NASA													
Solar Electro-Optical Network (SEON)	DOD/USAF													
Solar Terrestrial Relations Observatory (STEREO) satellites	NASA													
Sound Velocimeter for hydrographic surveys	DOC/NOAA													
Spatially Enhanced Broadband Array Spectrograph System (SEBASS)	NASA													
State and Local Stream Gage Networks	DOI/USGS	*			*		*	*			*			*
State and Local Water Level Networks	DOI/USGS													
Terminal Doppler Weather Radar (TDWR)	DOT/FAA							*					*	

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
Toxics Release Inventory (TRI)	EPA													
Tropical Rainfall Measuring Mission (TRMM) satellite	NASA		*		*				*					
U.S. Army Corps of Engineers Hydrographic Surveys	DOD/USACE													
U.S. Census Data on Population and Roads	DOC/ Census													
Unmanned Aircraft Systems (UAS) - Surveys and Surveillance	DOC/NOAA, DOD, DOI/USGS				*				*					
US Gap Analysis Program (GAP) - assessing biodiversity conservation	DOI/USGS													
USGS Geomagnetic Observatories	DOI/USGS													*
USGS In Situ Water Quality Sensors	DOI/USGS	*	*		*						*			



Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
USGS Inner Shelf Vessels for Benthic Habitat Observation	DOI/USGS													
USGS National Groundwater Stations	DOI/USGS				*		*	*						
USGS Water Quality Samples	DOI/USGS				*									
Very Long Baseline Interferometry (VLBI)	NSF													
Voluntary Observing Ships (VOS)	DOC/NOAA		*					*				*		
Water Resources Field Experiments	DOI/USGS													
WC-130 - U.S. Air Force - Hurricane Hunter aircraft	DOD/USAF		*						*		*	*		
WMO Global Observing System (GOS) - Surface	Non-USG				*	*					*			

	Contributes	Moderate	High	Very High	Highest
Impact:	*				

Observation System (Alphabetical Order)	Agency	Ag&Frst	BioDiv	Climate	Disasters	Ecosys	Energy	HumanHlth	Ocn&Cstl	Space Wx	Trans	WaterRes	Wx	RefMeas
WMO Global Observing System (GOS) - Upper Air	Non-USG			*		*								
World Aviation Forecast System Internet File Services (WIFS)	DOT/FAA													

Note: The EOA value chain began by identifying high-impact data sets and information products, and then observing systems that generate or contribute to those data sets and information products. As a result, the EOA captured the impact of certain non-USG sources of data, including from international, non-governmental, and commercial partners. Furthermore, the EOA results are derived from the findings of the SBA subject matter experts, and may not reflect all uses of well-known observing systems. In the table above, an asterisk indicates that the EOA scored this system as contributing to the SBA but not at a moderate or high level.

Annex II: Caveats for Understanding and Interpreting the 2012 Earth Observation Assessment

1. Comprehensiveness. The list of systems assessed in the EOA and identified in Annex I of this National Plan is not a comprehensive inventory of all systems, but rather an analysis of systems with significant impact as identified by a broad range of subject-matter experts. In addition, the EOA results include only the current portfolio of deployed systems. Planned and future systems (JPSS, NEON, etc.) were not analyzed. Finally, the EOA does not encompass the full range of possible objectives within each SBA. Therefore, certain agency mission objectives and systems important to those objectives may not be adequately reflected.

2. Significance of All Systems. All systems identified in the EOA have significant impact on key objectives identified by expert teams under each SBA.

3. Assessment Results and the Budget Process: Impact vs. Value. The EOA did not include cost data. Therefore, the EOA results convey **the impact, not the value**, of the observing systems identified by expert teams. The Assessment and this National Plan are meant to provide useful input to the budget-review process and to complement (but not substitute for) information and methods traditionally used in these reviews.

4. Considering the Enterprise as a Whole. The list of high-impact observing systems in Annex I is best used as a device for understanding the relative impact of each system on the broader, national Earth observation enterprise. Decisions about observing systems in one agency can have a dramatic effect (positive or negative) on the ability of other agencies to perform their Earth-science missions. Earth-observation investment decisions and adjustments must therefore be made through a coordinated process to avoid unintended consequences on the entire enterprise. For example, the EOA results alone should not be used as the basis for eliminating individual systems. Such a rough-cut use of this system would have devastating effects on specific areas of Earth science and services delivered to taxpayers.

5. Even Weighting of the SBAs. The work of the EOA is organized around evenly weighted "Societal Benefit Areas," because an economic analysis of the value of the information to society is well beyond the scope of the EOA. Therefore, the list shows relative, rather than absolute priority, across all areas. It is appropriate to review the EOA results not just in the larger list, but by SBA to see how the relative impact of a given system rises or falls, depending on the area of emphasis.

6. Multiple- and Special-Purpose Systems. Reviewers of these results should understand that systems with a high impact across multiple SBAs score highest in the EOA. Nevertheless, many significant systems that did not meet the criteria established for Tier 1 (i.e., impact across *many* SBAs) are considered essential to the *specific* SBA they uniquely serve. Many of these High-Impact Special Purpose Systems are included in as Tier 2 systems, listed in Table 2 in Annex I.

7. A Companion to Other Analyses of Research-Observing-System Priorities. The analysis presented here is best understood as a companion to other analyses of Earth-observation priorities that are provided

to the Federal Government, most importantly the National Academies report *Earth Science and Applications from Space* (2007), known as the decadal survey. The EOA provides two new perspectives to complement the work of the decadal survey: (a) the inclusion of non-satellite systems and (b) a robust analysis of the impact of all systems on the delivery of services to society. Fundamental research about the Earth system underpins each of the 12 SBAs, and each team was invited to consider research priorities critical for their area. The EOA process, however, was fundamentally applications-oriented, and the constraints of time and the breadth of the analysis prevented a full accounting of research needs in every area. Therefore the Assessment's results for research observation systems may not reflect the full impact of those systems on climate and other research needs. Aside from this dimension, the EOA does capture the impact of current research systems on specific societal-benefit applications.

8. International Interests. The Nation's Earth-observing systems have important impacts on U.S. foreign-security-policy interests that were not included in this analysis. Agency commitments and agreements with international partners on collaborative systems were also not factored into the impact analysis.

Annex III: Abbreviations

ACRIMSAT	Active Cavity Radiometer Irradiance Monitor
AMDAR	Aircraft Meteorological Data Relay
APHIS	Animal and Plant Health Inspection Service, Department of Agriculture
BEDI	Big Earth Data Initiative
BISON	Biodiversity Information Serving Our Nation
BLM	Bureau of Land Management, Department of the Interior
CDC	Centers for Disease Control and Prevention, Department of Health and Human Services
CENRS	Committee on Environment, Natural Resources, and Sustainability
CERES	Clouds and the Earth's Radiant Energy System
CO2	carbon dioxide
COSMIC	Constellation Observing System for Meteorology, Ionosphere, and Climate
CYGNSS	Cyclone Global Navigation Satellite System
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
DSCOVR	Deep Space Climate Observatory
ECV	Essential Climate Variable
EOA	Earth Observation Assessment
EPA	Environmental Protection Agency
ESA	European Space Agency
FAA	Federal Aviation Administration, Department of Transportation
FAS	Foreign Agricultural Service, Department of Agriculture
FHWA	Federal Highway Administration, Department of Transportation
FIA	Forest Inventory and Analysis, United States Forest Service, Department of Agriculture
FEMA	Federal Emergency Management Agency, Department of Homeland Security
FSA	Farm Service Agency, Department of Agriculture
FWS	Fish and Wildlife Service, Department of the Interior
FY	fiscal year
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GOES	Geostationary Operational Environmental Satellite
GPM	Global Precipitation Measurement
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
HHS	Department of Health and Human Services
ICESat	Ice, Cloud, and land Elevation Satellite

IOOS®	Integrated Ocean Observing System
ISRO	Indian Space Research Organisation
ISS	International Space Station
JPSS	Joint Polar Satellite System
LIDAR	Light Detection and Ranging
MDCRS	Meteorological Data Collection and Reporting System
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service, Department of Agriculture
NEOTF	National Earth Observation Task Force
NOAA	National Oceanic and Atmospheric Administration, Department of Commerce
NPS	National Park Service, Department of the Interior
NRCS	Natural Resources Conservation Service, Department of Agriculture
NSF	National Science Foundation
NSTC	National Science and Technology Council
OCO	Orbital Carbon Observatory
OMB	Office of Management and Budget
OMPS	Ozone Mapping and Profiler Suite
OSTP	Office of Science and Technology Policy
PACE	Preliminary Advanced Colloids Experiment
POES	Polar-orbiting Operational Environmental Satellite
RFI	Request for Information
S-NPP	Suomi National Polar-orbiting Partnership
SAGE	Stratospheric Aerosol and Gas Experiment
SAM	Stratospheric Aerosol Measurement
SAR	Synthetic Aperture Radar
SBA	societal benefit area
SI	Smithsonian Institution
SMAP	Soil Moisture Active Passive
SME	subject matter expert
SORCE	Solar Radiation and Climate Experiment
SWOT	Surface Water Ocean Topography
TCTE	Total solar irradiance Calibration Transfer Experiment
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TIM	Total Irradiance Measurement sensor
TSIS	Total Solar Irradiance Sensor
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USFS	United States Forest Service, Department of Agriculture
USG	United States Government
USGEO	United States Group on Earth Observations
USGS	United States Geological Survey, Department of the Interior
USN	United States Navy
VIIRS	Visible Infrared Imaging Radiometer Suite