2019 National Plan for Civil Earth Observations

A Report by the

U.S. Group on Earth Observations Subcommittee

Committee on the Environment

of the

NATIONAL SCIENCE & TECHNOLOGY COUNCIL

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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 to ensure science and technology policy decisions and programs are consistent with the President's stated goals. The NSTC prepares research and development strategies that are coordinated across Federal agencies aimed at accomplishing multiple national goals. The work of the NSTC is organized under committees that oversee 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 to provide the President and others within the Executive Office of the President with advice on the scientific, engineering, and technological aspects of the economy, national security, homeland security, health, foreign relations, the environment, and the technological recovery and use of resources, among other topics. OSTP leads interagency science and technology policy coordination efforts, assists the Office of Management and Budget with an annual review and analysis of Federal research and development in budgets, and serves as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the Federal Government. More information is available at http://www.whitehouse.gov/ostp.

About the U.S. Group on Earth Observations Subcommittee

The United States Group on Earth Observations (USGEO) is chartered as a subcommittee of the NSTC Committee on Environment. The Subcommittee's purpose is: to plan, and coordinate Federal Earth observations, research, and activities; foster improved Earth system data management and interoperability; identify high-priority user needs for Earth observations data; and engage international stakeholders by formulating the United States position for, and coordinating U.S. participation in the intergovernmental Group on Earth Observations (GEO).

About this Document

This document was developed by the USGEO Subcommittee in response to the National Aeronautics and Space Administration Authorization Act of 2010 (42 U.S.C. § 18371 [2014]), which called for the Director of OSTP to establish a mechanism to ensure greater coordination of the research, operations, and activities relating to civilian Earth observation.

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Use of this Document

The purpose of the National Plan for Civil Earth Observation is to help coordinate Federally-supported Earth observations and investments, identify opportunities to advance Earth observations, and achieve national Earth observation policy objectives. This plan serves as a resource to assist Federal departments and agencies (hereafter, “agencies”) in their planning, coordination, identifying high-leverage research and development opportunities, and avoiding unnecessary duplication and redundancy. This plan should help inform the normal budget process through which resources are allocated. Under the NSTC which has the responsibility to ensure R&D is coordinated across Federal departments and agencies, the USGEO Subcommittee will use this plan to coordinate implementation of the recommended actions.

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Abbreviations and Acronyms

AI	Artificial Intelligence
ARSET	Applied Remote Sensing Training
BAER	Burned Area Emergency Response
CIO	Chief Information Officer
DOE	Department of Energy
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
GEO	Group on Earth Observations
GOES	Geostationary Operational Environmental Satellite
GRACE	Gravity Recovery and Climate Experiment
GSICS	Global Space-based Inter-Calibration System
IOOS	Integrated Ocean Observing System
JACIE	Joint Agency Commercial Imagery Evaluation
JPSS	Joint Polar Satellite System
LTER	Long-Term Ecological Research Program
NASA	National Aeronautics and Space Administration
NEON	National Ecological Observatory Network
NIH	National Institutes of Health
NOAA	National Oceanic and Atmospheric Administration
NSTC	National Science and Technology Council
NSF	National Science Foundation
OSTP	Office of Science and Technology Policy
R&D	Research and Development
RA	Regional Associations
S&E	Science and Engineering
SI	Smithsonian Institution
STEM	Science, Technology, Engineering, Mathematics
USDA	United States Department of Agriculture
USGEO	United States Group on Earth Observations
USGS	United States Geological Survey
VOI	Value of the Information

Executive Summary

Earth observations impact our lives every day. The United States relies on a robust system of observations that provide accurate and timely measurements of the physical, chemical, geological, and biological parameters of Earth. Here, observations mean any measurement and information obtained from space-based, aircraft-borne, ship-borne, ocean, and land-based sensors, as well as surveys, and also including reference systems such as the Global Positioning System. Information from the Earth observing sensors and systems enable individuals and organizations to make informed decisions that boost the economy and to ensure national security and public safety. The United States Government invests billions to provide Earth observations that may be mobile or fixed and are space-based, airborne, marine or in situ and ground based. Observations provided by the United States Government are made accessible to the greatest extent possible to advance human knowledge, to enable commercial sector value-added services, and for general public use.

At the same time, private companies are rapidly developing and deploying new observational technology and analytics. These companies design innovative products that combine business practices with Earth observations. The explosion of innovation and demand for advanced methods of analysis provide exciting opportunities for Federal agencies to reshape strategies for collection and use of Earth observations.

The Trump Administration is committed to continuing American global leadership in science and technology. For Earth observations this translates into leveraging the powerfully unique, mutually beneficial and collaborative roles of each sector of an Earth Observations Enterprise: Federal agencies; State, local, tribal, and territorial governments; world-leading colleges and universities; private industries; non-profit organizations; and Federal and National Laboratories involved in the collection and dissemination of observations; operation of enabling infrastructure; and end-users of Earth observation data.

This National Plan for Civil Earth Observations outlines the Administration's priorities and focuses the Nation's civil Earth observations efforts. It fosters coordination, collaboration, and robust dialog not only between departments and agencies but broadly across the entire Earth Observations Enterprise. The following goals, objectives, and specific actions will guide Earth observations activities:

- ***Goal 1:*** *Support and Balance the Portfolio of Earth Observations:* This goal focuses on the provisioning and availability of Earth observations collected by both the public, academic, and private sectors.
- ***Goal 2:*** *Engage the Earth Observations Enterprise:* This goal focuses on the long-term engagement with the Earth Observations Enterprise to accelerate the uptake and use of Earth observations.
- ***Goal 3:*** *Improve the Impact of Earth Observations:* This goal focuses on increasing the impact of Earth observations through innovative and multi-use applications; using systematic methods of understanding value; collaborating in international fora; and developing a skilled and capable workforce.

Goals	Objectives	DoE	DOI	EPA	NASA	NIH	NIST	NOAA	NSF	SI	STATE	USDA
Support and balance the portfolio of Earth observations	Prioritize the availability and continuity of Earth observations	●	●	●	●			●	●	●		●
	Implement innovative Federal procurement and acquisition strategies		●		●			●				●
	Strengthen R&D capabilities that enhance usability	●	●		●		●	●	●	●		●
	Provide long-term stewardship	●	●		●			●		●		●
Engage the Earth Observations Enterprise	Strengthen coordination within the Earth Observations Enterprise		●		●		●	●			●	●
	Coordinate R&D of experimental technologies and techniques		●		●			●	●			●
	Recognize and analyze program models for leveraging data as a strategic asset		●		●			●		●		●
Improve the Impact of Earth Observations	Articulate the value of Earth observations	●	●		●	●		●	●	●		●
	Improve the Earth observation portfolio through introduction of new technologies including learning and adaption	●	●	●	●	●		●	●			●
	Promote and leverage international collaborations		●	●	●			●		●	●	●
	Develop a skilled and capable workforce		●		●			●	●	●		●

The table above lists the goals and objectives under this strategic plan and the departments and agencies that are involved in Earth observation activities. The dots indicate the objectives each agency currently plans to contribute to through mission-specific actions, subject to budgetary constraints and other approvals.

Introduction

Empowered by bold ideas, America's leadership in global Earth observations[1] protects lives, property, and the environment, and promotes American prosperity and security. From agriculture and active forest management to regional weather forecasts and transportation apps on personal cellular devices, Earth observations are a significant but often invisible part of our lives. Farmers use Earth observations, along with the Global Positioning System (GPS) and Geographic Information Systems (GIS), for crop management to maximize yields and operating profits. Ship operators use nautical charts, oceanographic and meteorological information to transport more than half of the goods used by Americans daily. Municipalities use Earth observations to manage city infrastructure. For example, the Great Lakes provides drinking water and recreation for nearly eleven million Americans; in 2014, 400,000 residents in the Toledo, Ohio area could not drink the water because of a toxic algal bloom. Satellite, aerial drones, and direct water quality observations identified and helped predict the location of the toxic blooms and were used to alert the public to take preventive measures. Among new and exciting areas of observations, marine eDNA and acoustic technology are emerging as ways to track where fish and other species are swimming and it will soon be possible to leverage these new observations to enhance ocean observations and systematically address questions of ecosystem connectivity from estuarine habitats to deep ocean environments far offshore.[2]

The role of Earth observations has long been recognized in the forecasting of, preparation for, response to, and recovery from extreme weather events and natural disasters. With today's computer technologies, Earth observation data are also combined with economic and demographic data to improve disaster responsiveness and minimize disruption to the local economy. Hurricane Florence, which made landfall in North Carolina in 2018, serves as an illustrative case for the role of Earth observations through all phases of an extreme event. The National Oceanic and Atmospheric Administration (NOAA) accurately predicted Hurricane Florence's track five days in advance of its landfall, which contributed to the North Carolina officials being well-prepared to reduce deaths and damages to property, prioritize emergency health care, and pre-position mobile emergency response equipment. During the hurricane, Earth observations were used to monitor conditions to continually adapt the response.

The Department of Commerce's Census Bureau, Bureau of Economic Affairs, the United States Economic Development Administration and NOAA provide essential demographic and economic data online to report and assess cumulative impacts of hurricanes on counties and businesses. Post-Hurricane Florence, Earth observations were used to aid restoration of services like electricity, water, and transportation. Also, post-storm the Federal Government worked to restore livelihoods. For example, the United States Department of Agriculture (USDA) used Landsat, Sentinel, and aerial imagery to assess and quantify flood damage to crops, to determine payments to farmers for crop insurance.

[1] Earth observations measure the physical, biological, chemical, and geological characteristics of the Earth. Observations can be space-based, aircraft-borne, ship-borne, and in-situ, surveys and include reference systems such as the GPS. Along with physically observed data, geographic, human dimensions, and economic data are important for understanding impacts.

[2] Global Observational Needs and Resources for Marine Biodiversity; Front. Mar. Sci., 23 July 2019 https://doi.org/10.3389/fmars.2019.00367

The Trump Administration recognizes the important linkage among Earth observations, public safety, and economic resilience and has supported initiatives in Earth observations. In the past two years, NASA and NOAA launched six satellite or instrument missions to support the forecasting of weather and severe storms and the measurement of carbon, water movement, plant stress, and ice elevation and thickness.[3] In June 2019, NOAA, USDA, and the United States Geological Survey (USGS) established the first National Soil Moisture Network in response to the Northern Plains drought. The Administration also has reduced the processing time for the permitting of commercial satellites to foster the growth of the multi- billion-dollar space sector.

The Administration continues to support Landsat 9 via the joint NASA/USGS Sustainable Land Imaging program to continue the 47-year Landsat record of global, land-imaging measurements. Additionally, agencies are exploring how to best leverage the growth in commercial Earth observation capabilities while sustaining the data infrastructure needed by both the commercial and government sectors of the Earth Observations Enterprise. NOAA has awarded $6 million dollars to three companies through its Commercial Weather Data Pilot Program and NASA, through its Small Satellite Commercial Data Buy Program, awarded $7 million dollars to three small satellite vendors and is evaluating their data for its Earth science research and applications objectives.

[3] Missions Include: JPSS-1; GOES-17; ECOSTRESS; ICESat-2; Orbiting Carbon Observatory 3; and GRACE Follow-on.

The present United States Earth observation systems and applications serve to stimulate the demand for Earth observations. Through increased commercial provisioning of infrastructure and the advancement of analytical technology, new applications using Earth observation data are being pioneered. Companies are developing and deploying new observational technology and analytics at record speeds, which advance the development of innovative products that combine business practices with Earth observations. This explosion of innovation and demand for advanced methods of analysis provides an opportunity for Federal agencies to evolve their strategies for Earth observations and data collection.

Partnerships within an Earth Observations Enterprise

"*America is now entering a Second Bold Era of its Endless Frontier in Science and Technology. The Second Bold Era is one in which we must take an enterprise-wide view; understand and leverage the powerfully unique, mutually beneficial and collaborative roles to be played by each sector; create new strategies for partnering to leverage the amazing assets across the enterprise; and remove inefficiencies and unnecessary encumbrances that arose over the past several decades."* - Dr. Kelvin Droegemeier, Director of the White House Office of Science and Technology Policy[4]

The Trump Administration is committed to continuing American science and technology leadership in this Second Bold Era. Success in advancing the collection, use, and application of Earth observations will depend, in large part, on the Administration's ability to leverage new and creative partnerships and collaborative frameworks. This multisector enterprise consists of Federal agencies; State, local, tribal, and territorial governments; world-leading colleges and universities; private industries; non-profit organizations; and Federal and National Laboratories, hereafter referred to as the Earth Observations Enterprise. Together, the Earth Observations Enterprise is collectively involved in the acquisition, analysis, dissemination and use of Earth observations; the operation of enabling infrastructure; sustaining and advancing the creation of data and information products; maintaining routine uses; and developing innovative applications for societal, environmental, and economic progress. The Enterprise approach recognizes existing collaborations but also opens new opportunities for partnerships for the provisioning and analysis of Earth observations.

Structure of the National Plan for Civil Earth Observations

The National Plan for Civil Observations[5] (hereafter "Plan") aims to inspire action across the Earth Observations Enterprise because the Enterprise profoundly impacts the provision, uptake, and use of Earth observation data, touches the lives of all Americans every day, and enables new discoveries. Recognizing the important Federal role in the Earth Observations Enterprise, the Plan provides current and potential partners with insight into the United States Government's Earth observation direction, goals and activities. The Plan was written to foster coordination, collaboration, and robust collective dialog not only between departments and agencies but broadly across the entire Earth Observations

[4] American Association for the Advancement of Science Keynote Address, February 20, 2019; https://www.aip.org/fyi/2019/droegemeier-outlines-agenda-first-speech-ostp-director

[5] 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.

Enterprise. Strong coordination of these sectors improves America's ability to bolster infrastructure resilience; advance observational capabilities; retain American science and technology leadership; and improve Earth system prediction capabilities by leveraging the power of Earth observation data and fostering strong research environments. All parties in the Earth Observations Enterprise can use this Plan for making their own research and development plans and investments.

This Plan lays out three goals:

- ***Goal 1:*** *Support and Balance the Portfolio of Earth Observations:* This goal focuses on maintaining a balanced and robust Earth observation portfolio that leverages the strengths of all Earth Observations Enterprise partners to provide public services, research in the public interest, and private sector innovation and growth. Although Federal agencies rely on a core set of Federally funded observations to conduct their missions, this goal recognizes the rapidly advancing commercial sector in providing innovations and new concepts and products in both observation systems and analytical services. Federal agencies, in cooperation with other members of the Enterprise, will lead the development of new and agile ways of working together to take advantage of these capabilities.
- ***Goal 2:*** *Engage the Earth Observations Enterprise:* This goal focuses on creating mechanisms for more coordinated engagement across the Earth Observations Enterprise. The components of the Earth Observations Enterprise are heterogeneous in their composition and culture. Therefore, understanding this landscape is important to build mutually beneficial relationships.
- ***Goal 3:*** *Improve the Impact of Earth Observations:* This goal focuses on the value of Earth observations and data to decision making. Increasing the use of Earth observation data, products, and services will enhance their value and improve return on the billions of dollars that the United States invests in this area annually. The United States is a leader in championing the sharing of Earth observation information globally and will remain engaged in international coordinating bodies advocating for and promoting accessible data policies. This plan recognizes that a diverse and capable workforce with strong skills in geospatial fusion, visual analytics, data science, and machine learning is essential for jobs of the future.

In the following sections, each goal is described and supported by strategic objectives. For each objective a set of actions have been identified. The Executive Summary contains a table listing the departments and agencies planning to contribute through mission-specific actions, subject to budgetary constraints and other approvals.[6]

[6] This plan is intended to inform the policy development process. Any commitment of Federal resources to support the activities outlined in this document will be determined through the budget process.

Goal 1: Support and Balance the Portfolio of Earth Observations

A bold new era for American science and technology leadership requires strengthening and leveraging Earth Observations from Federal agencies, commercial companies, educational institutions and non-profit organizations. These are strategic assets that increase the effectiveness of public services, enable new discoveries, support research, and grow the American economy. This goal focuses on creating an Earth observations portfolio that provides the best value to meet Federal agency missions and the needs of the American public and business sectors, regardless of whether observations are collected by public or private sources. This Plan prioritizes expanding the purchase of Earth observations data and services from the private sector and/or through public-private partnerships. This practice is supported by the following legislation: (1) Weather Research and Forecasting Innovation Act of 2017[7], (2) NASA Administration Authorization Act of 2018[8], and (3) National Integrated Drought Information System Reauthorization Act of 2018[9].

A sustained portfolio of core, Federally-funded Earth observations provides the foundation for agencies to provide public safety functions and the increasing use of those resources by the American public. This approach frees the Earth Observations Enterprise to explore new, disruptive techniques and technologies. It also allows Federal agencies to diversify observing options at an acceptable risk level. To further enable innovation, this goal focuses on reducing barriers for engagement with the private sector and incentivizing the use of innovative acquisition approaches to meet Federal Earth observation data needs. The intended outcome is for Federal agencies to adopt innovative technologies from the private and academic sectors faster and provide a path for on-ramping commercial solutions that support agency missions.

Earth observation activities are categorized as "sustained" or "experimental."

- Sustained: Provides continuity that is an enabling factor for private sector products and services.
- Experimental: Provides new data that advances human knowledge through enabling basic and applied research, testing and evaluating technical innovations, and improving public services.

Together, sustained and experimental observations provide the basis for innovation, while ensuring the provision of data and information upon which many users rely.

To build a robust Earth observation portfolio that responds to multiple opportunities, the national observing enterprise, which encompasses the full value chain from observations to end-user benefits, must be reliable, based on open and accurate data, open to new partners, and trustworthy. To achieve this, the Enterprise depends on continued investment, strong partnerships with industry and academia, innovations in science, technology, new applications and commercial products, optimization of observing activities, and a workforce capable of advancing and using Earth observations.

Objectives for Goal 1:

- Prioritize the availability and continuity of Earth observations;
- Implement innovative Federal procurement and acquisition strategies;

[7] Pub. L. No. 115-25
[8] Pub. L. No. 115-10
[9] Pub. L. No. 115-423

- Strengthen research and capabilities that enhance usability;
- Provide long-term stewardship

For each objective, technical and programmatic intent is described, with actions identified to achieve the objectives.

Prioritize the availability and continuity of Earth observations

Increasingly, Earth observation systems are used by multiple Federal agencies to support objectives that go beyond the original intent of the observation system. Therefore, when a sponsoring agency decides to end support for or modify a given observing system, it may have unintended consequences for other agencies or users. The United States Group on Earth Observations (USGEO) subcommittee, comprised of Federal agencies, is the forum for collective discussion on the formulation of new missions, changes to existing systems, possible instrument decommissioning, and continuity planning of observing infrastructure that supports multiple agencies' missions. USGEO enables informed decision-making for the Federal Earth observation portfolio. The USGEO subcommittee also creates a setting whereby agencies can explore ways to mitigate the loss of an observing system, if decommissioning is required. Historically, discussions on these issues at the Federal level have occurred in an ad-hoc fashion. Under this Plan, agencies will develop a formal framework and process for addressing continuity challenges and new observing system opportunities that have ramifications for multiple agencies.

It is important to understand the ability of the Earth Observations Enterprise to provide the information needed to maintain crucial public services, enable new discoveries, and advance knowledge. These abilities may change over time due to changes in levels of funding, coordination, readiness, recapitalization, reliability, and redundancy. Understanding the impact and interdependencies across the Earth Observations Enterprise can help ensure essential capabilities are maintained, lead to improvement in performance, and broaden the use of Earth observing assets. Although Earth observations have revolutionized many industries, their full impact often goes unrecognized because they may be deeply embedded in decision- and planning- support tools. By cataloging and better understanding which Earth observations are used, or could be used across economic sectors such as agriculture; manufacturing; transportation; energy; insurance; retail; and recreation, more informed decisions can be made as to whether present investments and/or improvements in Earth observation systems are adequate or whether new systems should be undertaken.

Earth observation data are important for addressing issues across a wide range of timescales, from monitoring short-term events to recognizing long-term trends. Between episodic events, like natural disasters, and the longer-term monitoring like that associated with ecosystem response/resilience or urban planning, Earth observations, modeling, and forecasting in the medium-temporal range (i.e. Sub-seasonal to seasonal timescales) have the potential to significantly impact decision-making in sectors as diverse as maritime planning, emergency management, agriculture, water resources, public health, and energy.[10] Studies of these mid-term timescales, however, have lagged behind those on shorter and longer-term time frames. Given the rise in catastrophic extreme events that have taken place in the last several years, causing billions of dollars in damage each year, Federal agencies will focus on providing increased use of Earth observation data to assist in short, medium and long-term

[10] National Academies of Sciences, Engineering, and Medicine, Next Generation Earth System Prediction: Strategies for Sub seasonal to Seasonal Forecasts, 2019; www.nap.edu

planning related to wild fires, extreme weather events, drought and water management, and human health.

Actions that support this objective are:

- *Develop a framework and guiding principles for USGEO that will improve interagency coordination on Earth observation investment decisions.*
- *Provide a prioritized list to the Office of Science and Technology Policy (OSTP) of Earth observation systems that are likely to be at risk in the next 2- 3 years.*
- *Analyze the strengths and weaknesses of the current Earth observation portfolio in terms of support of economic sectors.*
- *Work across the Earth Observations Enterprise to expand the use of Earth observations to improve skills in seasonal to sub-seasonal forecasting.*

Implement innovative Federal procurement and acquisition strategies

Partnerships among agencies and between the public and private sectors contributes to strengthen our Nation's technological base. The increase of commercially-operated Earth observation systems, coupled with the introduction of cloud and web services capable of enhancing their utility, provides new tools that can be explored to create mutually beneficial partnerships. New and on-going commercial capabilities enable Federal agencies to leverage external expertise and infrastructure; diversify data collections; accelerate innovation; improve missions; ensure efficient program schedules; and reduce costs. To take full advantage of research and development (R&D) across the Earth Observations Enterprise, especially with regard to the commercial sector, a forum to better understand non-Federal needs and desires when designing new Earth observing missions will be created. This forum can be used to examine the full landscape of potential vendors, market forces, and government policies and practices that present barriers to engaging and better serving the private sector. For example, while Earth observation data and services provided by the Federal Government employees are protected under the Federal Tort Claims Act (i.e., have liability insurance coverage), commercially procured Earth observation data and analytics are not. This creates challenges for both the Federal and private sectors. The agencies must perform additional quality checks on the commercial data which may hinder the use of this data. In some cases, the private sector is looking to the Federal Government for certification of their data to increase its usage. Thus, to advance the Earth Observations Enterprise, partners will work to develop new ways of data sharing and new types of license agreements where the roles, rights, and responsibilities of all parties are defined and where the allocation of risk is understood.

Federal agencies will explore and adopt innovative and new data purchase and exchange mechanisms to augment their government-owned and operated Earth observation portfolios with data acquired from commercial partners. For example, cloud-computing and technical-services vendors provide valuable insights and, potentially, resources to evaluate the feasibility of establishing an Enterprise data exchange that could facilitate commercial Earth observation acquisitions by public and private entities. Departments and agencies should also explore funding mechanisms to purchase Earth observation products in multi-year planning environments for datasets collected incrementally over multiple years.

To increase the Federal agencies' confidence in purchasing commercial data and commercially produced products, how these data are collected and processed must be fully understood. This includes understanding the observing instrument model and its characterization, sensor calibration,

data integrity, and interoperability with other systems. As data processing algorithms become available from the commercial sector, the Earth Observations Enterprise partners will work together to standardize issues such as code version documentation, data integrity and reproducibility, and transparency of data products. As agencies increasingly include commercial data in their portfolios, measures must be put in place to assure sustained access to the commercial data to avoid gaps in observational capabilities and both affordability and continuity of time series data collections. Ideally, when purchasing data, an agency should assess the cost and benefits of acquiring licenses that permit use and re-use of the data and images across all Federal agencies, Federal grantees; and, in some cases, State; local; tribal and territorial governments. Additionally, the academic research community who are or have been part of the development of the systems and applications would like continued access to these systems and data (processed and raw), once it is out-sourced to or provided from the commercial sector. This objective encourages proactive dialog between Federal agencies and the commercial sector to develop transparency in pricing schema, licensing arrangements, data access, and use/re-use and sharing agreements. This should lead to an increasingly robust and competitive market and best value and return on investment for the taxpayer.

Federal agencies will explore new solutions that take advantage of technological advancements, such as cloud-based storage, computing, and distribution, to enable greater data access and sharing. Efforts will also be made to reduce obstacles in the procurement and sharing of commercial data. As part of the Plan, agencies will explore whether a cloud-based clearing house concept, developed together with public and private partners, adequately addresses existing challenges in satellite image acquisition and dissemination, governance, and operational issues such as reliability and latency. This approach could form the foundation for future incentive-driven, public, commercial, and international Earth observations data-exchange programs.

Actions that support this objective are:

- *Work with commercial data providers and analytics companies to develop a set of best practices for commercial data buys.*
- *Explore mechanisms for piloting a market-driven clearing house for the procurement of Earth observations data and analytics.*
- *Identify shared agency needs related to land imaging and evaluate options for optimally addressing those needs with current resources through increased agency coordination.*

Strengthen research and capabilities that enhance usability

Scientific research fuels innovation. In order to maximize the strategic value of Earth observations, basic and applied research must be actively supported and encouraged to utilize the best available Earth observations. An approach that links Earth observations to basic science will lead to new scientific discovery, demonstrate improved predictions with emerging observational capabilities, and add value to future public services through adoption of new science. Streamlining this process is an important component to the Administration's priority to ensure that the United States remains at the forefront of global science to the benefit of the Nation.

Because Earth observation data inform decisions involving lives and livelihoods, the Earth Observations Enterprise must have data of assured quality that meets operational requirements, research objectives, and business practices. The Earth Observations Enterprise will establish mechanisms to document accuracy, precision, characterization, uncertainty, and calibration of Earth observation data. To enable seamless interoperability between datasets and data processing approaches and to ensure consistency

over time, as well as integration with data from other countries, performance metrics will be tied to the International System of Units (SI).[11]

Initiatives such as the Global Space-based Inter-Calibration System (GSICS), developed under the auspices of the World Meteorological Organization and the Coordination Group for Meteorological Satellites, provide a good and established model for accomplishing consistency and interoperability. For example, the use of GSICS has improved the usability of global infrared Earth observations through a comprehensive calibration strategy that involves: (1) monitoring instrument performance, (2) operational inter-calibration of satellite instruments, (3) tying measurements to absolute references and standards, and (4) recalibration of archived data.

Modeling and data assimilation, algorithm development, artificial intelligence (AI), and high-performance and cloud computing offer the potential to improve the value of Earth observations for users, creating incentives and opportunities for the private sector to develop value-added products, services, and applications. AI and machine/deep-learning techniques, including deep neural networks, have advanced considerably in recent years and have driven new commercial developments, tools, and utilities in fields as wide ranging as medicine, self-driving cars, social media, and finance. The increase in accuracy and applicability of AI has been significant in the private sector, driven by its efficiency, cost-effectiveness, and auto-learning features. Until recently, the adoption of AI to process Earth observation data has lagged. AI is now increasingly being applied with promising results, including development of applications with predictive capabilities. It is anticipated that this trend will continue with the ever-increasing volume of Earth observations data being collected, increased societal reliance resulting from improved forecasting accuracy and spatial and temporal resolutions, and increased availability of high-performance and cloud computing.

Applying AI to Earth Observations

Rationale:

- Volume, speed of data accumulation, and variety of Earth observation data can overwhelm traditional approaches for extracting information, patterns, and insights to support decision making.
- Finds patterns and extracts insights in an efficient manner.

Applications:

- Quicker advanced warnings for extreme weather events and natural disasters.
- Better understanding of the rates and resilience of ecosystems undergoing change by natural and/or anthropogenic processes, such as extreme weather events and wildfire combustibility of vegetation.

While AI that includes machine learning and deep learning shows great potential for analyzing Earth observation data, challenges still exist. For example, current deep learning approaches may not be optimal when system behavior is dominated by spatial and temporal contexts.[12] To extract the full value from Earth observations, the Earth Observations Enterprise will work to identify and share datasets and collectively improve approaches, including infrastructure, algorithms, best practices, and lessons

[11] On May 20,2019, the anniversary of the Treaty of the Meter, known as World Metrology Day, the SI was redefined to be based entirely on the speed of light and six other defining constants, resulting in the measurement system that might truly and finally be for all times and for all people.

[12] Reichstien, Markus et al; "Deep learning and process understanding for data-driven Earth system science, Nature, February 13, 2019; https://doi.org/10.1038/s41586-019-0912-1

learned for applying AI to Earth observation data. In addition, the focus on AI in the area of Earth observations will further the Administration's priority of strengthening American leadership in AI.[13]

AI, cloud computing platforms, and cloud-native applications enable the development of advanced analytics and data sharing capabilities necessary to support sensor cross-calibration so systems and data can work together. Federal agencies are presently exploring and, where appropriate, transitioning to cloud computing platforms following the lead of the private sector component of the Earth Observations Enterprise that already operates using commercial cloud services. This transition is not simply a technical evolution but necessitates that Federal agencies change certain aspects of their business models.

Actions that support this objective are:

- *Maintain support for basic and applied science utilizing Earth observations to enable the scientific discovery and development of new capabilities.*
- *Coordinate activities in basic science, applied research, modeling, algorithm development, machine learning, AI, and data fusion to improve the usefulness and value of Earth observations to end-users.*
- *Work in partnership with standards bodies and stakeholders to develop procedures for the calibration and inter-calibration of sensors, and advancing data assimilation and re-analysis of historical data.*
- *Identify best practices and coordinate investment for commercial cloud services and high-performance computing access and use, including management, adaptation, usage, and cybersecurity in coordination with the Federal Chief Information Officer (CIO) community.*

Provide long-term stewardship

Long-term stewardship of observations, analytical tools and information products is based on good data-management practices. Good data curation maximizes the utility of the Federal Government's investment in Earth observations. Data lifecycle management and scientific data stewardship services ensure that the results of observations and scientific research are available and usable by all, today and into the future. Data re-analysis is key for improving our understanding of Earth system processes over time and the performance of operational missions.

[13] Executive Order on Maintaining America Leadership in Artificial Intelligence, February 11, 2019;, https://www.whitehouse.gov/presidential-actions/executive-order-maintaining-american-leadership-artificial-intelligence/

To ensure future access and cross-system compatibility, efforts must include the adoption of standard procedures for the integration of new images and sensor data with historical data, understanding data biases and uncertainties, advancing reanalysis techniques, and improving the transition of research-to-operations. These, along with creating cross-calibrated time-series and analysis-ready data sets, maintain the continuity of long-term, quality-controlled, data series while also improving sensors, techniques, and technical infrastructure. Federal agencies should engage in coordinated, long-term stewardship of Earth observation data, standardization of vocabularies and metadata, and creation of information products and associated algorithms and processing software. Such efforts improve usability, enable rapid application development, lower costs, and improve the long-term sustainability of national data archives.[14] They also facilitate the exploration and implementation of innovative technologies that improve data discovery, access, interoperability, and usability as well as provide regular updates and the timely incorporation of data management practices and standards as they evolve. With the increase in purchasing of Earth observations data, the Earth Observations Enterprise partners will discuss how these data will be archived and stewarded.

- A core principle of the United States Government is that Federal Earth observation data are public goods, paid for by the American taxpayer, and that access to these data significantly enhances their value.
- Data, when shared, contribute to a robust United States Earth Observations Enterprise.
- The private weather sector and Ocean Enterprise both have hundreds of companies and together provide more the $15 billion annually in economic return. (NWS Enterprise Analysis Report, June 2017 https://www.weather.gov/media/about/Final_NWS%20Enterprise%20Analysis%20Report_June%202017.pdf); US IOOS-Ocean Enterprise Study https://ioos.noaa.gov/project/ocean-enterprise-study/)

Actions that support this objective are:

- *With the Federal Chief Data Officer Council, coordinate and encourage efforts in data stewardship technologies and techniques to improve Earth observation data discovery and usability.*
- E*xamine agency practices on how Federal funding opportunities are written to ensure that all Federally-funded project data are provided to a publicly accessible archive, consistent with Federal policies and regulations.*

[14] Federal Archive Centers include: NASA's Earth Observing System Data and Information System (EOSDIS), a distributed system with major facilities at NASA's Distributed Active Archive Centers (DAACs); NOAA's National Centers for Environmental Information (NCEI); USGS' Earth Resources Observation and Science (EROS) Center, and the National Archives and Records Administration.

Goal 2: Engage the Earth Observations Enterprise

The strength and vitality of the Earth Observations Enterprise depends on proactive collaboration and efficient coordination among all members. Federal agencies exchange data and information products with components of the Earth Observations Enterprise to provide public sector services as well as to support research to create knowledge that allows us to better understand the Earth system. The Federal Government's core Earth observation capabilities are strengthened by maintaining and expanding these important partnerships. State, local, tribal and territorial governments rely on open access to Federal Earth observation data to perform their public duties. Academic partners rely on them to make new discoveries and advance knowledge. Commercial partners rely on them for business operations and optimizing business performance.

Improving performance and realizing the economic potential of the Earth Observations Enterprise depends on understanding its components and how they interact. The commercial sector can be broadly characterized as providers, intermediaries, and end-users. Understanding this, however, by itself, is not enough because of the influence and involvement in social and environmental activities of the non-profit entities, professional societies, and industry clusters which are also heterogeneous in their make-up. To date, Federal agencies often have taken independent approaches with different components of the Earth Observations Enterprise. This Plan develops a coordinated strategy to foster stable, easily manageable, long-term relationships across all members of the Enterprise.

Understanding the perspectives of Earth Observations Enterprise components is necessary for success. For example, interagency engagement is often driven by leveraging one agency's mission with another agency's capability, while engagement within the private sector is often driven by revenue opportunities. Timelines, culture, financial resources, and missions are often different for the government, private sector, and academic institutions. Effective interactions require understanding expectations, agreeing upon roles and responsibilities, and respecting cultural differences of each component of the Earth Observations Enterprise. Furthermore, input from individuals outside the technical realm, (i.e., finance, insurance, and law) have the potential to accelerate agreement formation and reduce the financial and legal risk of agreements to all parties.

Objectives for Goal 2 are:

- Strengthen coordination within the Earth Observations Enterprise
- Coordinate R&D for experimental technologies and techniques.
- Recognize and analyze program models for leveraging data as a strategic asset.

Strengthen coordination within the Earth Observations Enterprise

Under this Plan, agencies will develop innovative engagement strategies across the Earth Observations Enterprise to better understand and address non-Federal user needs across the observational value chain.

As part of a USGEO engagement plan, agencies will explore mechanisms for soliciting feedback from members of the Earth Observations Enterprise regarding the need for potential new observing sensors and systems. Such sensors and systems may be satellite-based or ground/marine-based. Both are needed for a holistic understanding of the Earth and its processes. Space-based observing systems generally provide high-resolution data on large areas of Earth's surface and provide regional perspectives and linkages not possible with ground/marine arrays. On the other hand, those on the ground/marine provide data for calibration and more direct measurement of characteristics and

parameters that cannot be measured or determined from satellite images or sensing systems. The Federal Government has significant investments in both. Two examples of ground-based systems are the National Ecological Observatory Network (NEON) and the Long-Term Ecological Research Program (LTER), funded by the National Science Foundation (NSF). NEON consists of 81 ecoclimatic domain field sites across 20 United States and Puerto Rico, while LTER focuses on 28 sites across the United States, Puerto Rico, and Antarctica. Each site is instrumented with an array of sophisticated geo-, bio, and chemical sensor arrays and produces data and observations that help us understand feedbacks between plants, animals, soil, nutrients, water, and the atmosphere. Similarly, the United States Arctic Observing Network, funded, in part by a consortium of Federal agencies, is a broad network of long-term land, ocean, and ice observing systems that provide observations and data to understand the changes in the Arctic and their impacts both locally and globally. Federally-funded ocean-based observing systems, consisting of in-situ systems that include moorings; gliders; and cabled observatories, such as the Integrated Ocean Observing System (IOOS®) and the Ocean Observatories Initiative, provide chemical, biological, and physical oceanographic data for understanding of the ocean and feedbacks between the sea, land, atmosphere, and its ecosystems.

This combination of observational platforms results in opportunities for small and medium companies and non-profit entities to provide important services and work with the Federal sector. With the increasing presence and sophistication of innovation incubators and business accelerators, this Plan provides increased opportunities for integrating Earth observations into new product lines, applications, and analytics services. For example, a forum is proposed for the co-design of mid-timescale seasonal to sub-seasonal forecast products, including the development of verification metrics and decision-making tools.

When Federal agencies determine that a new or next generation of Earth observation system is needed, in accordance with Administration priorities and as appropriate, agencies will strive to engage with the full Earth Observations Enterprise to determine whether there is a commercial solution available or in process that might be more appropriate than creation of a Federal observing asset.

Actions that support this objective are:

- *Develop an engagement plan to understand and mitigate the constraints of coordination within the Earth Observations Enterprise.*
- *Work with commercial providers to understand issues, agency practices, and policies that foster development of small and medium businesses and start-ups.*
- *Create opportunities for the Earth Observations Enterprise to provide feedback during the formulation of significant new observing systems.*

Coordinate R&D of experimental technologies and techniques

The Federal Government and the academic and business sectors have roles in supporting the transition of experimental technologies to the marketplace. NSF's 2018 biennial Science and Engineering Indicators states "The United States holds a preeminent position in science and engineering (S&E) in the world, derived in large part from its long history of public and private investment in S&E research and development and education. Investment in R&D, science, technology, and education correlate strongly with economic growth and with the development of a safe, healthy, and well-educated society." [15] According to that report, United States R&D funding in S&E totaled nearly $500 billion in

[15] National Science Board, Science and Engineering Indicators;

2015, and the business sector accounted for more than two-thirds of this total. To advance and retain global leadership, Earth Observations Enterprise activities must include an enterprise-wide basic R&D component. Frequently, Federal research dollars are considered "seed" or "glue" funds because they are used to initiate exploration and development activities considered too risky or experimental in other sectors. Thus, the Federal Government plays a key role in enabling new discoveries that can then be adopted by other Earth Observations Enterprise members to lay the foundation for sustainability of Earth observations through commercialization and/or the leveraging of funding from other sources.

"The United States must continue to lead the world in technology, and that means maximizing both the taxpayers' investment into American R&D and the potential of our Nation's brightest minds across academia, industry and government. We must ensure the next great inventions are not stifled in regulatory limbo forever, but rather they are brought into the marketplace safely and efficiently for the benefit of the American people." Deputy Assistant to the President for Technology Policy Michael Kratsios, of the White House Office of Science and Technology Policy[16]

Strategic investment in R&D within the Earth Observations Enterprise catalyzes the development of new observational data processing technologies and applications. This objective provides an entry point for Earth observation application development across the Earth Observations Enterprise to promote and facilitate the commercialization and advancement of Earth observation platforms and applications. In the past, competitions, prizes, and grand challenge opportunities have been effective in accelerating applications development. Additionally, agencies are increasingly looking to innovative business incubators and accelerators to hasten the pace of technology transfer. The Department of Defense has established the Air Force Research Laboratory and Catalyst Space Accelerator and the Defense Innovation Marketplace to support technology transfer. The NSF funds the Science Gateway Community Institute, which provides online interfaces that give researchers, educators, and students easy access to specialized, shared resources specific to different science and/or engineering disciplines. The Scientific Gateway Community Institution allows connections to or between instruments, data collections, specialized software, and/or high-performance computing. These examples and other similar Federal programs create an environment that accelerates technology transfer.

Actions that support this objective are:

- *Perform a feasibility study to advance the Earth Observations Enterprise through activities such as accelerators, incubators, and industry clusters.*
- *Engage with the Earth Observations Enterprise to identify high priority research areas and explore mechanisms for coordinating investments to advance experimental technologies and techniques.*
- *Work together to scope an open-competition program that combines innovative Earth observation data sourcing, including identifying pathways for development and metrics to recognize and measure incubator success.*

Recognize and analyze program models for leveraging data as a strategic asset

This Administration has set a cross-agency priority for making Federal data, whose collection has been paid for by the taxpayers, accessible and useful to the American public, businesses, and researchers to

https://www.nsf.gov/statistics/2018/nsb20181/assets/1407/digest.pdf

[16] https://www.nist.gov/news-events/news/2019/04/nist-releases-findings-increasing-innovation-impacts-federally-funded-rd

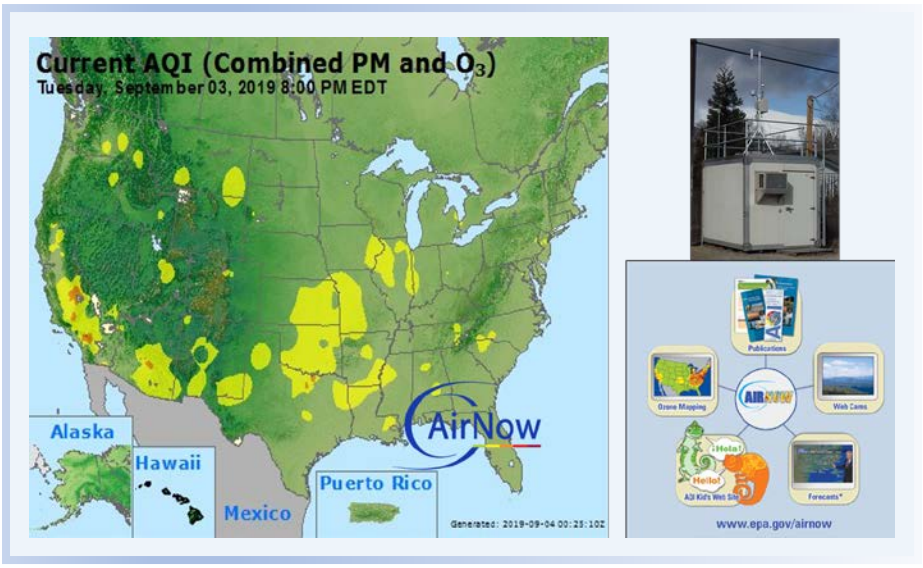
accelerate and promote economic growth and the development of new and improved applications and their commercialization. The President's Management Agenda lays out the long-term vision for modernizing the Federal government and identifies data, accountability and transparency as one of three key focus areas.[17] As part of the Management Agenda the Administration published the Federal Data Strategy, June 2019, which defines a framework to use Federal data as a strategic asset to grow the economy, increase effectiveness of the Federal Government, and promote transparency through consistent data infrastructure and practices.[18] There is increasing interest across the Earth Observations Enterprise in combining Earth observations from diverse platforms to improve the temporal, spectral, and spatial content for environmental, resource, and economic applications. However, the ability to effectively leverage multi-source Earth observational data depends on the degree to which they are discoverable, described, standardized, and made interoperable.

Best practices for collection and release of Federal data exist, but are generally not well documented or disseminated. Thus, it is important to collect these practices and determine if they can be used more broadly. For example, best practices already developed in some agencies could be used by others to more readily adopt validated commercial data streams to augment agencies' holdings. This could motivate commercial entities to develop additional innovative capabilities. For instance, the advent of small satellites and CubeSats changes how we think about hardware requirements. Data from small satellites could be cross-calibrated with the highly characterized Federal systems. This would promote use of this new inexpensive infrastructure, provide new data, and potentially reduce Earth observing costs. The Joint Agency Commercial Imagery Evaluation (JACIE) is an example of a multi-agency, industry, community collaboration that compares and characterizes civil and emerging commercial and international land imaging systems and data. It began in 2000 with a primary focus on satellite imagery and has now expanded to include airborne and in-situ remote sensing systems, systems calibration, product validation, and science application assessments. JACIE could serve as an example for similar initiatives within the Earth Observations Enterprise to dramatically improve radiometric, geometric, and spatial data accuracy and their use by single or multi-system architectures.

[17] President's Management Agenda; https://www.whitehouse.gov/wp-content/uploads/2018/03/The-President%E2%80%99s-Management-Agenda.pdf

[18] OMB Memorandum - Federal Data Strategy – A Framework for Consistency; https://www.whitehouse.gov/wp-content/uploads/2019/06/M-19-18.pdf

Programs such as AirNow, IOOS, and the National Soil Moisture Network have formal mechanisms for linking in-situ, remote sensing, and modeling products from Federal, State, local, and tribal governments; academia; and industry. The Environmental Protection Agency, in cooperation with other Federal, State, and local agencies, developed the AirNow system to provide the public with convenient access to realtime national air quality and health information. Participating agencies report air quality measurements for locations across the United States and Canada. Many agencies also provide daily air quality forecasts. AirNow transforms those measurements and forecasts into national products using EPA's Air Quality Index (AQI), which provides health effects information that can help the public plan to reduce or avoid exposure to harmful levels of air pollution. IOOS is a national-regional partnership providing integrated ocean, coastal, and Great Lakes information in near real-time, as well as retrospectively to improve safety, facilitate economic activity, and protect the Nation's coastal environment. IOOS is composed of 17 Federal agencies; 11 non-Federal Regional Associations (RAs); the Alliance for Coastal Technologies, a technology validation and verification organization; and the IOOS Coastal and Ocean Modeling Testbed. The IOOS RAs operate 46 percent of the 370 coastal moorings; 100 percent of the high frequency radar network, the largest in the world; the majority of the glider capability; and serve up millions of observations. The IOOS RAs have achieved certification by NOAA, renewable every five years, for data management practices. This extends tort liability protection to the Regional Associations as non-Federal data providers and managers.[19] A final example is the National Soil Moisture Network that integrates in-situ, remote sensing and modeling products from Federal, State, and citizen science sources and supports the United States Drought Monitor Program delivery of improved drought predictions and mitigation products.



It is not sufficient to simply collect Earth observation data. Data must be translated into products and services that address and support national, regional, and local challenges. Often Earth observations, under grants awarded by the Federal Government, are only available from that entity. This Plan recommends procedures be put in place so Federal awardees will be required to make their data and data products available, at the national level via submission to publicly accessible Federal archives. This requires proactive communications and simplified practices and procedures for the ingestion and curation of such data in Federal data repositories and the strengthening of sharing requirements in proposal solicitations. Agencies will consider and streamline pathways for the preservation of Federally-collected data at the start of every mission and Federally-funded external project.

[19] http://www.ioosassociation.org/sites/nfra/files/documents/Advocacy/U.S.%20IOOS%202018%20Approps%20Report%20to%20Congress.pdf

Actions that support this objective are:

- Explore existing programs for evaluating observation sources (e.g. JACIE) and provide recommendations for improvement or expansion of such models.
- Identify and evaluate existing models for Federal/non-Federal provision of Earth observations and web services to highlight areas for increased engagement.
- Engage in a focused, short-term initiative to discover new Earth observations from non-Federal sources and determine paths for making the data discoverable and accessible.

Goal 3: Improve the Impact of Earth Observations

The economic and societal benefits of Earth observations have the potential to transform our lives and communities. The impact of Earth observations can be magnified when data, produced by public and private stakeholders both domestically and internationally, are integrated with economic, demographic, and statistical data to understand the interdependence of processes under investigation. Such information should be reexamined, over time, to understand how resulting information can be used in interesting, new, and better ways, including visualization in multiple dimensions. New observations serve as a backbone of basic research that will lead to new discoveries, improved societal capabilities, and strategic economic value.

Determining the value of Earth observations begins with knowing the users' perspectives of the questions to be answered, the problems to be solved, and whether answers and solutions will be facilitated by Earth observations. This knowledge can then be used to calculate the social, economic, and societal impacts of Earth observations.[20] Prior to the development of the Plan, the Federal agencies, through OSTP and USGEO, conducted the 2016 Earth Observation Assessment providing a census of Federal Earth Observation systems, sensors, networks, and surveys. The assessment serves to demonstrate how Earth observations affect all American citizens' lives and wellbeing in a multitude of ways every day. Beyond quantified and/or monetized assessments of the impacts of Earth observations, the development of compelling narratives has become an established method for understanding how Earth observations impact the lives of Americans. Employing this capability, throughout the Earth Observations Enterprise, serves the collective interest because it demonstrates the value proposition of Earth observations, the analytic services derived from them, and the influence they have on people's daily lives.

The Geospatial services sector, which is built upon Earth observations, generates $400 billion in revenue a year, employs approximately four million people in jobs directly related to generating, processing, and using the observations and delivers customer benefits of over $550 billion annually.[21] A skilled workforce well versed in data science and data assimilation techniques is needed to fully extract the value from existing and new Earth observations.

The strategic objectives for Goal 3 are:

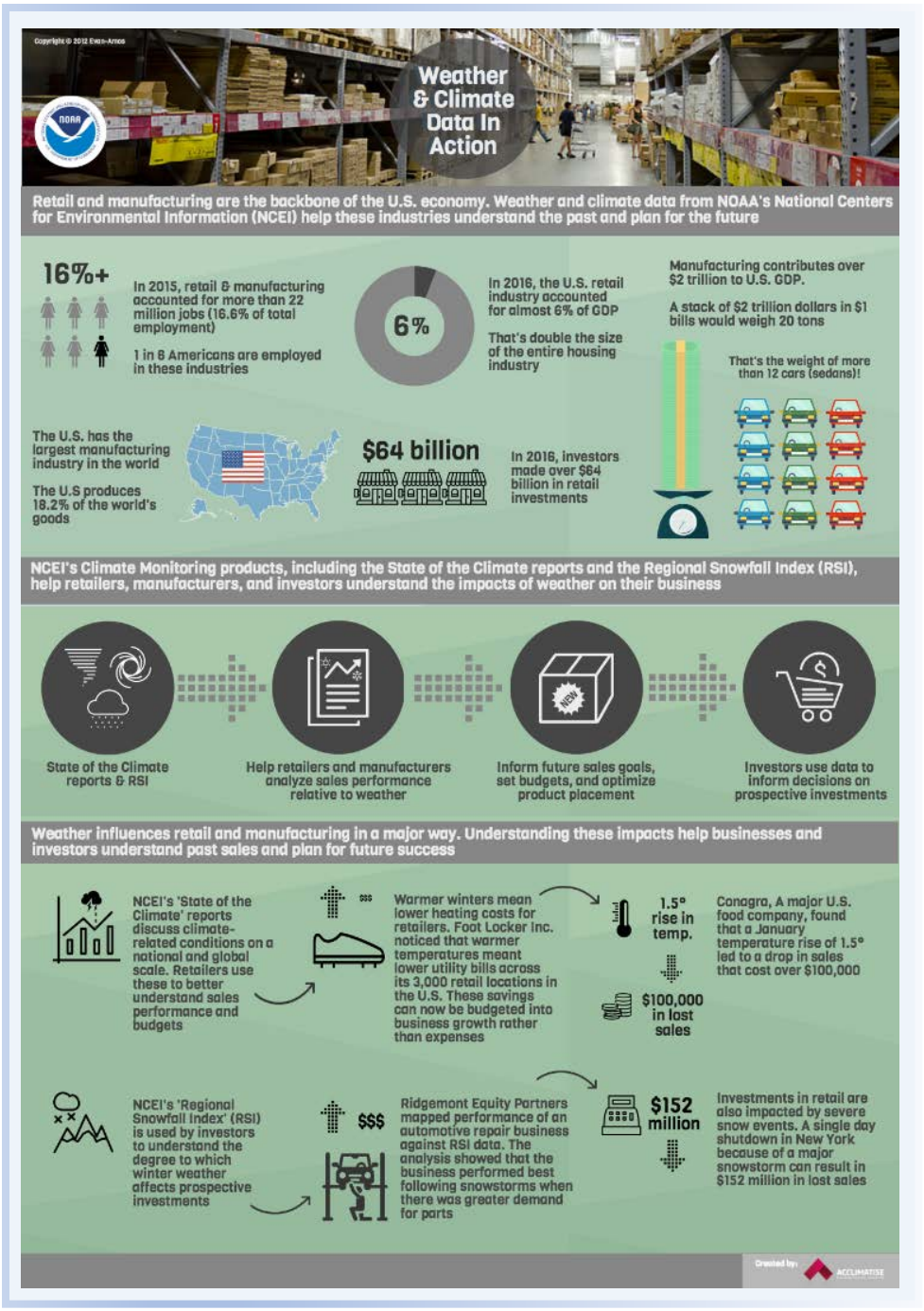
- Articulate the value of Earth observations;
- Improve the Earth Observation portfolio through learning and adaption;
- Promote and leverage international collaboration;
- Develop a skilled and capable workforce.

Articulate the value of Earth observations

[20] Pearlman, F., Lawrence, C.B., Pindilli, E.J., Geppi, D., Shapiro, C.D., Grasso, M., Pearlman, J., Adkins, J., Sawyer, G., and Tassa, A., 2019, Demonstrating the value of Earth observations—Methods, practical applications, and solutions—Group on Earth Observations side event proceedings: U.S. Geological Survey Open-File Report 2019–1033, 33 p.; https://doi.org/10.3133/ofr20191033

[21] Alphabeta. (2017). The Economic Impact of Geospatial Service: How Consumers, Businesses, and Society Benefit from Location-Based Information; http://www.alphabeta.com/wp-content/uploads/2017/09/GeoSpatial-Report_Sept-2017.pdf

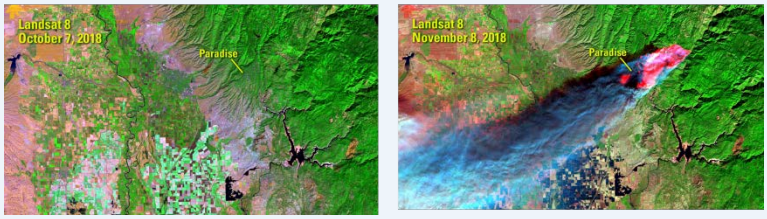
Earth observation data are strategic assets that support improved policy and decision making related to natural resource management, hazard response and management, weather and climate, agriculture, transportation, human health, environment, and navigation. Uncertainties in results and predictions are also reduced where there is routine availability of Earth observations.



Earth observations, collected through Federally funded programs, are considered public goods and therefore are used by many groups simultaneously without the fear of depleting the supply. Further they are non-exclusionary because observations collected via tax payer dollars are available to all at no or minimal cost. Public-good, Earth observations provide benefits by supporting natural disaster preparation and response; greater understanding of the role of the Earth system in weather and climate; policy formulation; and effective environmental stewardship. Thus, using market information to assess the economic value of Earth observations providing societal benefits is difficult. In addition, Earth observations are rarely used in isolation. Therefore, it is difficult to separate the benefits of Earth observations from other parts of the system, such as software, visualization, and analysis. For these reasons, this Plan advocates the development of testbeds and pilot programs for understanding both the monetary and non-monetary benefits of Earth observations.

Studies to analyze the benefits of Earth observations generally consist of case studies that look at the impact of Earth observations on specific local uses (e.g., beach closures, port operations, etc.). Such case studies are difficult to aggregate and compare. Therefore, there is a growing realization by Earth observation providers and data producers that understanding the benefits on regional and global scales is needed. At present, the community lacks a consistent set of evaluation techniques and metrics which, if available, would result in better measures of the impact of Earth observations. To address this issue, NASA created the Resources for the Future VALUABLES consortium that is developing, documenting, and training Enterprise partners on systematic methods for measuring how satellite information benefits people and the environment when it is used to improve and inform decisions. VALUABLES began by working with an interdisciplinary team to develop an estimate of the economic value of the information (VOI) for the Gravity Recovery and Climate Experiment (GRACE) satellite. The team determined that the GRACE mission provides data that improves decisions for both drought monitoring and flooding.[22] Using the VOI framework, VALUABLES examined the cost effectiveness of using Landsat imagery as part of the Federal Burned Area Emergency Response (BAER) program that identifies imminent and post-wildfire threats to human life and safety, property, and natural and cultural resources. The study compared the cost of producing the Burned Area Reflectance Classification using Landsat or commercial satellites to the cost of producing the product using only aerial imagery. The VOI analysis showed that Landsat data was the most cost-effective input into the BAER, resulting in a cost savings of up to $35 million over a five-year period.[23]

Landsat: NASA/USGS partnership to provide land change and land cover



A fierce wildfire devastated Palisades, California in November 2018. Landsat data was used to understand how fire transforms the land surface by measuring how this transformation alters the ecosystem. For example, burned soils resist rainwater infiltration, leading to increased runoff, erosion, land slides and flooding. Satellite data help identify, locate and map those burned areas most susceptible to the increased runoff and erosion. Fire response teams then treat burned sites with a variety of measures to minimize erosion, such as spreading ryegrass seeds to stabilize the soil, and placing straw mulch on hill slopes for ground cover to intercept rainfall before it hits the burned soil.

NOAA has been collecting data on the economic importance of the sectors NOAA supports, the costs of natural environmental hazards, and the value of NOAA activities that help society and commerce prepare for a constantly changing environment. In 2018, NOAA published *NOAA's Contribution to the Economy report*, to describe the agency's impact on the United States economy and its role across vital industry sectors.[24]This strategic approach has been recognized internationally. The international Group

[22] https://journals.ametsoc.org/doi/full/10.1175/WCAS-D-16-0044.1
[23] https://media.rff.org/documents/Valuables_Wildfires.pdf
[24] NOAA. 2018. NOAA's Contribution to the Economy; Powering America's Economy and Protecting Americans; http://performance.noaa.gov/economics

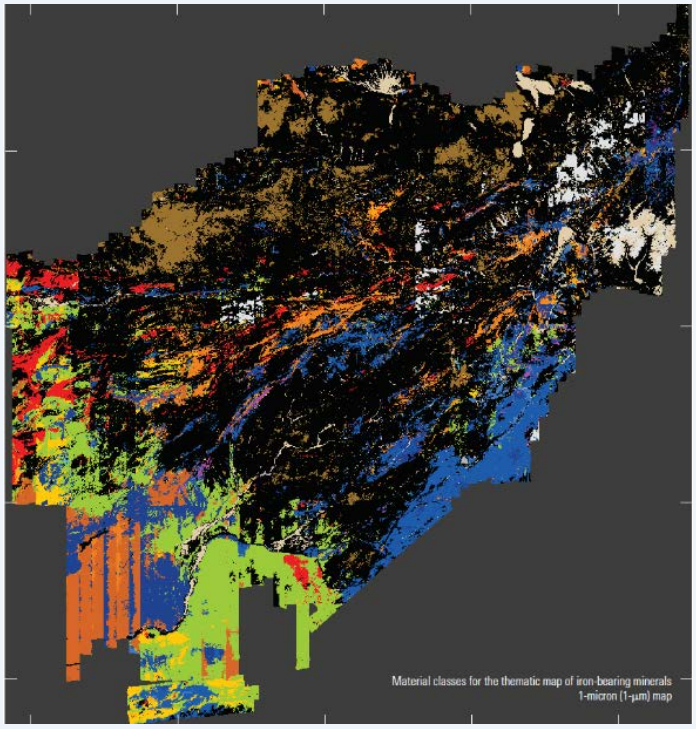
on Earth Observations (GEO) has established the GEOValue community of practice to help the international community develop robust methods to measure the indirect and societal benefits of Earth observations.[25] For example, in July 2019, USGS and NOAA co-organized a meeting hosted by the European Space Agency that resulted in improved valuation methods and practices used to determine the economic and societal benefits of Landsat and the European Copernicus satellite.

Actions that support this objective are:

- *Collect current agency-commissioned economic studies and synthesize the state-of-knowledge on the economic value of Earth observations, including their return-on-investment, ability to accelerate innovation, and contributions to economic growth.*
- *Develop a catalog of ways to quantify the social and economic value of Earth observations. Collect, catalog, and publish qualitative narratives and quantitative examples on the benefits of Earth observations.*

Improve the Earth observation portfolio through introduction of new technologies, including learning and adaption

The Plan encourages agencies to continuously assess the optimal mix of Earth observation data sources and information for carrying out Federal agency missions and management of Earth observation assets, programs, and partnerships. Proposed practices include identifying important data dependencies, gaps, and common approaches for acquiring observations from new and emerging sources. The approach promotes the identification and cross-agency use of Earth Observations Enterprise partner data and services. It also accelerates the evaluation and integration of novel technologies, techniques, and cutting-edge research and allows for the optimization of future Earth observation architectures and systems. The ongoing awareness of how Earth observations are used results in better informed investments;



Thematic map of iron-bearing minerals, vegetation, and water features on Afghanistan's land surface (251,000 mi^2), from airborne hyperspectral imagery. (Interpretation by Kokaly et al., 2013, USGS Data Series 787; work conducted in partnership with the Department of Defense, United States Agency for International Development, United States Trade and Development Agency, and Afghan government.)

[25] http://www.geovalue.org/

increased use, both within and outside the Federal Government; and more efficient collaboration across Earth Observations Enterprise partners.

In a significant advance for economic sectors ranging from mineral resources to agriculture, technologies such as hyperspectral imaging can now be deployed at national and global scale. For example, an interagency and international partnership provided Afghanistan national coverage of airborne hyperspectral imagery and geophysical surveys. Combined, these data types can provide a powerful three-dimensional understanding of Nations' shallow and buried mineral resources, in addition to land cover and vegetation characteristics. However, these techniques are not yet fully utilized. The Afghanistan hyperspectral dataset is larger than any dataset collected in the United States, and less than five percent of the United States is covered by modern geophysical surveys.

USGEO has established a Federal Satellite Needs Process that identifies civil agency space-based Earth observation needs. The Satellite needs process surveys civil agencies every two years about how they use current, or could use future, satellite observations to achieve agency missions. Agencies provide information about which data are necessary such as derived data products and measurement of spectral, temporal, and spatial resolutions. This information is provided to NASA for assessment and use in NASA's budget planning process. This approach has greatly increased Federal agency interaction and added new products to the suite of existing services based on present and future planned NASA missions. USGEO will provide information regarding the Satellites Needs Process to the Earth Observations Enterprise.

Actions that support this objective are:

- *Advance analytical tools and capabilities to analyze the Earth observation portfolio for chokepoints, useful measurements, dependencies, and connections to commercial data.*
- *Conduct a biennial satellite needs process that includes an analysis showing how each agency has implemented or applied the available satellite data to meet the agency mission objectives.*

Promote and leverage international collaboration

Earth observations transcend national boundaries. International partnerships enable the United States Earth Observations Enterprise to leverage the skills, assets, and resources of other countries to meet our domestic missions and provide opportunities to advance United States observing capabilities. Federal agencies collaborate with international partners, bilaterally and multilaterally, to collect a wide range of atmospheric, oceanic, and land-surface observations and deploy assets, with one of the goals being the development of applications and services that support decision-making.

To ensure effective collaboration with partners across the value chain, the United States participates in multiple international coordination groups. Federal agencies participating in these groups enhance communication and coordination between countries and with one another in an effort to enhance and bolster United States efforts and convey United States Earth observation policy in a consistent manner to the global community.

The United States promotes the accessible sharing of Earth observations data by the international community, a concept presently still not fully embraced by all overseas Earth Observing partners. United States Federal agencies will continue to work collectively with partners to identify where data sharing is unequal and uneven, and leverage United States assets and leadership to encourage and promote increased openness. Federal Agencies will identify and address structural issues that put domestic partners at a disadvantage internationally, including addressing issues such as differing public-private partnership regulations and research data embargoes.

Actions that support this objective are:

- *Enhance international cooperation to enable more robust Earth observation architectures.*
- *Work through international frameworks to increase access to data from overseas sources. Promote and advance United States interests by ensuring a level-playing field.*
- *Strengthen global and regional leadership through engagement in the intergovernmental GEO and advancement of AmeriGEO.*[26]

Develop a skilled and capable workforce

A strong, innovative, skilled, and diverse workforce supports efforts across the entire Earth Observations Enterprise and is one of its greatest assets. The United States needs a workforce that can collect, analyze, use, and commercialize products using Earth observations and geospatial data to foster innovation and remain competitive in the global economy. Partners in the Earth Observations Enterprise have developed training programs that provide the foundation for growing such a workforce. NSF contributes to the development of a diverse and skilled workforce, as well as new technologies and computational tools through its portfolio of university research and education programs as well as scholarship opportunities that support learning about and using Earth observations. These include: (1) internships that exchange personnel between universities and industry (2) opportunities for students to work in other Federal agencies, (3) interdisciplinary university-industry teams that conduct collaborative research projects where industry provides research expertise and where university faculty and students provide intellectual leadership and gain experience in the private sector.[27] NSF also provides opportunities for faculty and students to design and launch small satellites to collect unique datasets through its CubeSat Program for geospace and atmospheric research.[28] It also provides research experiences for undergraduates (i.e., the NSF Research Experience for Undergraduates Program) through eight week summer research programs that engage undergraduates in authentic research on cutting-edge topics in all areas of science, some of which involve the use and development of remote sensing, Earth observations and associated computer science algorithms. Other agencies also provide personnel exchanges and initiatives to provide free or reduced-cost geospatial analysis software and computing resources to students. NASA has developed extensive

Results of National Academies Study- Future of United States Workforce for Geospatial Intelligence (2013):

- Five subject areas identified: geospatial intelligence fusion, crowdsourcing, human geography, visual analytics, and forecasting.
- New capabilities include: 3-D and spatiotemporal visualization, linking geolocation data to social media and spatial analysis.
- Integrated approaches that cover all five areas are not adequately supported by present degree programs.

[26] AmeriGEO is a framework that promotes collaboration and coordination among the GEO members in the Americas that focuses on four societal benefit areas: Agriculture; Disaster risk reduction; Water; and Ecosystem Monitoring; https://www.amerigeoss.org/

[27] The NSF INTERN Dear Colleague Letter; https://www.nsf.gov/pubs/2018/nsf18102/nsf18102.jsp and the NSF GOALI Dear Colleague Letter; https://www.nsf.gov/eng/iip/goali.jsp.

[28] NSF solicitation: CubeSat Science Missions for Geospace and Atmospheric Research Program; https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503172

online training materials via its Applied Remote Sensing Training program. Training topics include: disaster risk assessment, synthetic aperture radar, conservation, geostationary satellite remote sensing and more. Additional education and training resources are also discussed in the National Science and Technology Council's (NSTC) Committee on Science Technology Engineering and Mathematics (STEM) Education, which recently released its 5-Year STEM Education Strategic Plan.[29]

The development and maintenance of a capable workforce is a long-term pursuit with collective benefits to the Earth Observations Enterprise. For the United States to maintain leadership in STEM, it must draw upon the best and brightest from all groups. Statistics show that women, people of color and other disadvantaged groups are under-represented in STEM. This plan will support activities that can increase the participation of these groups in STEM. Further, as global connections increase, innovation and new ideas are created when STEM talent from across the globe cooperate by bringing their own unique talent and views to tackle problems.

Across the Earth Observations Enterprise, activities to characterize career pathways and identify and make known the competencies and credentials associated with success, continue to attract new, diverse contributors and innovators. Near-term pursuits by this Administration lay the path for the availability of expertise in Earth observations for decades to come. Additional strategies that the Earth Observations Enterprise could employ include reviewing Federal occupation categories and tracking them in various labor markets, requiring competencies for employment, and expanding opportunities for the Earth observation workforce, especially in the context of research opportunities at Federal agencies.

Data science, AI, and machine learning are explosively growing fields with relevance to Earth observations. The AI Executive Order[30] calls for training the next generation of AI researchers and users and engaging with the NSTC Subcommittee on Machine Learning and AI and the Federal CIO council to ensure skills appropriate to Earth Observations are brought to the fore.

Comprehensive Earth observation education must go beyond teaching how to use Earth observation data. It should also include teaching about how to develop new instrumentation and use the present Earth observing assets to ensure the United States remains a global leader in instrument development and manufacturing. The timeline to develop and deploy a satellite or satellite system is long. Therefore, it is important that a long-term approach to addressing these educational and workforce needs and requirements has similar longevity.

Actions that support this objective are:

- *Assess the landscape of geospatial workforce training, including existing geospatial and Earth observations training cooperative initiatives and fellowships, and identify and address knowledge and workforce gaps.*
- *Develop roadmaps that show pathways to careers that utilize Earth observations. Facilitate connections with education programs to develop an Earth observing workforce.*
- *Explore how to make Earth observations data and educational materials available for use in classrooms to stimulate early and continued interest in Earth and analytical sciences.*

[29] https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf
[30] See Footnote 13