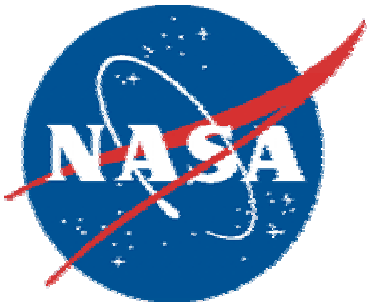
EARTH SCIENCE ENTERPRISE
APPLICATIONS STRATEGY
for
2002-2012



National Aeronautics and Space Administration

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Preface

The Applications Program serves the National Aeronautics and Space Administration (NASA) Earth Science Enterprise (ESE) and the Nation by demonstrating practical uses of NASA sponsored ***observations*** from remote sensing systems and ***predictions*** from scientific research. NASA implements projects through partnerships with public, private, and academic organizations. These partnerships focus on innovative approaches for using Earth science information to provide decision support that can be adapted in applications nationwide.

The ESE Applications strategy builds on the strategies and results of the ESE Research & Technology Programs. The focus of the ESE Research Strategy[1] is on answering one overarching Earth science question and five related science questions:

How is the Earth system changing, and what are the consequences for life on Earth?

- *How is the global Earth system changing?*
- *What are the primary causes of change in the Earth System?*
- *How does the Earth system respond to natural and human-induced changes?*
- *What are the consequences of change in the Earth systems for human civilization?*
- *How can we predict future changes in the Earth system?*

The ESE Technology Program supports the ESE Research Program by developing advanced technology and tools associated with orbital and sub-orbital missions using innovative remote sensing technologies. ESE currently provides measurements from Terra, QuickScat, Landsat 7, Jason and other missions[2]. ESE plans to launch the Aqua mission in 2002 and the Aura mission in 2003. Missions including the Gravity Recovery and Climate Experiment (GRACE), the Cloud Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) and CloudSat provide additional measurements for focused scientific research objectives. Measurements are also supported through data buys, including ocean color imagery from SeaWiFs, high resolution optical imagery from IKONOS, QuickBird and other private sector satellites, and land cover data from Landsat Data Continuity Mission (LDCM).

This document describes the direction of the ESE Applications Program for the period from 2002 through 2012. Building on the NASA vision and ESE mission, the document includes the Program mission and goals. Program planning strategy and the concept of operations to implement the strategy are described. The document also identifies performance measures by which to evaluate the program. The vision, mission, goals, and strategy are consistent with higher-level guidance and the plan is also consistent with requirements of other Federal agencies to meet their goals and objectives in support of U.S. national policy. Also included in this document are appendices that define key terms (Appendix A), present relevant directives (Appendix B), provide a profile of representative application projects (Appendix C), and provide references (Appendix D).

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[1] The NASA, ESE Research and Technology Strategy documents are accessible at www.earth.nasa.gov.

[2] Detailed mission information is available at www.earth.nasa.gov.

NASA EARTH SCIENCE ENTERPRISE
APPLICATIONS STRATEGY FOR 2002-2012

CONTENTS

NASA Earth Science Enterprise Applications Strategy

1.0 Vision, Plan, Missions, and Goals

1.1 NASA Vision

The NASA Strategic Plan (2000) states the NASA vision as:
NASA is an investment in America's future. As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth.

The Earth Science Enterprise (ESE) Applications Program contributes to the NASA vision by enabling organizations and people in the public and private sectors to routinely deliver and use Earth science information that saves lives, improves the quality of life, and saves resources through improved decision making.

Specific elements of the ESE contributions to the vision are:

- Providing enhanced and improved space-derived observation data to improve accuracy and duration of weather predictions
- Providing the Federal agencies with appropriate data and information about Earth science (e.g., weather, climate, and natural hazards) to enhance existing, and develop new, products and services that can be delivered through state, local and tribal organizations to serve citizens
- Providing critical Earth science observations, data assimilation, research, and modeling in support of weather, climate, and natural hazard research needs for decision support and policy-making

NASA works with its partners to establish America as an international benchmark for effective applications of Earth science information and related models.

1.2 ESE Heritage and Plans

NASA continues to build upon its experience and heritage working with the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) to deliver spaceborne observations that are used in computer models to provide weather predictions. Since 1960, NASA has developed space-based missions to provide observational parameters enabling the NOAA National Weather Service to predict the weather. NASA technology advancements in building weather instruments, coupled with improved capabilities for weather prediction modeling, contribute to the current capability of three-day forecasts with associated accuracies on the order of 93 percent. Since 1972, NASA has provided the Landsat satellites for mapping and monitoring of land cover and land use. Landsat continues to set the standard for global land observations providing decision support to the U.S. Geological Survey (USGS), U.S. Department of Agriculture (USDA), National Imagery and Mapping Agency (NIMA) and organizations around the world.

In the next ten years, NASA's Earth Science Enterprise plans to increase the duration and accuracy of forecasts in weather, climate and natural hazards (see Table 1). These increases in accuracy depend on scientific research in climate variability, atmospheric

composition, changes in water cycle, changes in carbon cycle, changes in ecosystems, and solid Earth and natural hazards. By achieving these increases in accuracy, NASA will contribute to providing a sound scientific basis for national policies and economic decision-making on resource management, global change[3] and natural hazards.

NASA also serves an operational community with these data and information about the Earth system. While the heritage of NASA Earth science has been with NOAA's weather and climate monitoring organizations that serve the nation's weather forecasters and broadcasters, other operational users require data and information integrated and packaged into "systems" to deliver reliable products and services to citizens. NASA identifies organizations with the appropriate information infrastructure to apply NASA results from Earth science to meet observations needs to help manage forest fires, coastal environments, agriculture, impacts of infectious diseases, aviation safety, and hurricane forecasting (see Appendix C). Such national and international needs will continue to evolve, and the Applications Program works to enable NASA contributions to help meet the evolving needs. ESE plans to provide annual updates to this strategy, with comprehensive reviews through the National Research Council on a 3-year cycle.

Table 1 – ESE Plans for Predictive Capabilities

	TODAY	GOALS for 2010
Weather	3 day forecast at 93%* 7 day forecast at 62%* 3 day rainfall forecast not achievable Hurricane landfall +/- 400km at 2-3 days Air quality day by day	5 day forecast at >90% 7-10 day forecast at 75% 3 day rainfall forecast routine Hurricane landfall +/-100km at 2-3 days Air quality forecast at 2 days
Climate	6-12 month seasonal prediction experimental; achieved an understanding of El Nino mechanics Decadal climate prediction with coarse models and significant uncertainties in forcing and response factors	6-12 month seasonal prediction *routine*12-24 months experimental 10 year climate forecasts experimental; moderate to high confidence in forcing & response factors
Natural Hazards	Demonstrate centimeter-level measurement of land deformation Accurate characterization of long-term tectonic motions, but no short-term earthquake forecast capability Accurate characterization of volcanic activity, but no long-term prediction accuracy	Continuous monitoring of surface deformation in vulnerable regions in with millimeter accuracy Improved temporal dimensions of earthquake & volcanic eruption forecasts Improve post-eruption hazard assessment
**Accuracy refers to sea level pressure forecasts over Northern Hemisphere during winter.*		

Source: ESE Overview Presentation, 2001

[3]*Our Changing Planet: The FY 2002 U.S. Global Change Research Program*, p. 2.

NASA supports scientific research and policy by providing critical Earth system science observations, data assimilation, research results and modeling as part of the U.S. Global Change Research Program. NASA's unique space-based Earth observations also serve essential global change and solid Earth and natural hazard research needs of the National Science Foundation, USDA, Department of Defense (DoD), Department of Energy (DOE), Department of the Interior (DOI), Environmental Protection Agency (EPA), and Department of Health and Human Services and National Institutes of Health (HHS/NIH). NASA research and observations are employed in international scientific assessments by such organizations as the World Meteorological Organization, the Food and Agriculture Organization of the United Nations, the United Nations Environment Program, and the Intergovernmental Panel on Climate Change. The knowledge and information needs of organizations are expected to grow substantially in the coming decade, thus providing additional opportunities for NASA applications of remote sensing technologies, data, and programs.

To demonstrate the applicability of evolving Earth system science knowledge, NASA works with USDA, NOAA, DoD, DOE, DOI, EPA, HHS/NIH, Federal Emergency Management Agency (FEMA), the Army Corps of Engineers (Corps), NIMA, Department of State, and others at the Federal level, and with a variety of state, local, and tribal organizations. NASA and its partners extend research and developments in observations, processing, data assimilation, and modeling to serve national priority needs for a range of spatial information requirements for decision support.

1.2 ESE and Applications Missions

As defined in the ESE Strategic Plan (2001), the NASA ESE mission is to:
Develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations.[4]

Consistent with the ESE mission, the Applications Program mission is to:
Expand and accelerate the realization of societal and economic benefits from Earth science, information, and technology.[5]

Implementing the Applications Program mission and realizing societal and economic benefits requires NASA and its partners to focus on solutions that are citizen-centered, results-oriented and market-driven. As shown in Figure 1, *operational solutions and applications* that benefit the public are enabled by systematically relating appropriate results of remote sensing and *applied research* in weather, global climate change, and natural hazards. Applied research, in turn, is enabled by *basic research and technology* developments in Earth science. The relationship among basic research and development, applied research, and operational solutions is dynamic and iterative. NASA evaluates operational and commercial solutions providing observations, communications, and computing capabilities for their capacity to support both basic and applied research in

[4]Earth Science Enterprise Strategic Plan 2001. See www.earth.nasa.gov.
[5]*Ibid*.

Earth science. Peer reviewed research from the biogeophysical sciences establish the foundation for the basic and applied research in Earth science and applications.

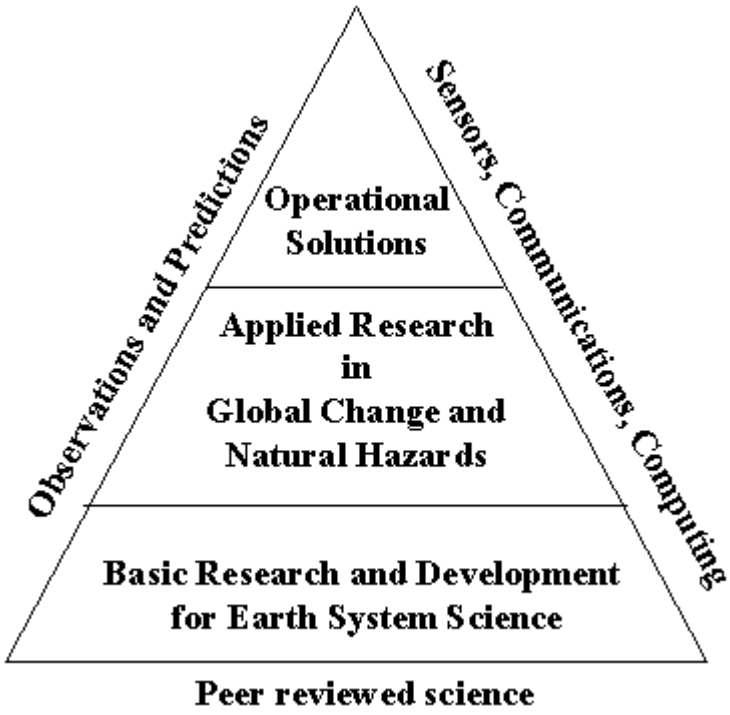

Figure 1 – Earth Science Pyramid

1.3 Applications Program Goals

While recognizing the inevitability of changing circumstances, the Applications Program mission is focused on specific goals to support the NASA vision and ESE mission. These goals are broadly defined to be flexible and effective in responding to changing circumstances, yet consistent enough over time to encourage the long-term growth of expertise and understanding of user needs. The overarching goal for the Applications Program is *to bridge the gap between Earth system science research results and the adoption of data and prediction capabilities for reliable and sustained use in decision support.* Related goals include the following:

- Simplify and integrate the use of Earth system science data and prediction results for adoption in national applications that enable decision-making.

- Enhance the availability, interoperability, and utility of ESE and U.S. private sector data sets, communications, computing and modeling capabilities as inputs to serve specific applications and research.

- Produce prototypes, guidelines, assessments, and documentation of project results that are citizen-centered, results-oriented and market-driven.

- Enable the project results to serve as benchmarks for policy and operational uses that benefit citizens through our Federal, state, local, and tribal partners.

2.0 Program Planning Strategy

The program planning strategy[6] for accomplishing the vision, mission, and goals focuses on identifying and selecting the highest priority national needs and opportunities. In this

[6] This section describes the direction and approach for the strategy for the ten-year period from 2002 – 2012.

context, national needs include initiatives identified by the Executive and Legislative branches of the Federal government and the national programs conducted in support of the missions of Federal agencies, and in concert with state, local, and tribal organizations. There is a wide range of potential applications of ESE data and predictive capabilities. To systematically address application priorities in the national interest, ESE conducts its strategy for program planning in three stages.

2.1 Identification of Candidate Applications

NASA ESE leadership[7] identifies candidate applications in terms of their potential to serve existing national needs. ESE considers candidate applications based on the extent to which they exhibit the following characteristics:

- Identified as a national priority by the Executive and/or Legislative branches
- Relevant to national program(s) of one or more Federal agencies
- Requirements validated (by other agencies) with the potential to be served by Earth science and remote sensing research and development results
- Significant societal and/or economic value in terms of clearly defined metrics, such as quality of life improvements, potential lives saved, and economic or resource savings

ESE profiles candidate applications projects using a systems-level "roadmap" showing relationships among Earth system science, remote sensing activities and related technologies being conducted by ESE and other organizations, potential applications, and desired outcomes and expected impacts. NASA management works with objective third parties to conduct independent assessments of candidate applications using pre-established guidelines and metrics.

2.2 Prioritization/Selection of Applications

ESE evaluates candidate applications projects based on criteria that are consistent with the ESE Research Strategy.[8] Reviews of candidate applications conform to the schedule associated with the Federal budget process in terms of preparing plans for out-year activities. The criteria for prioritizing candidate applications (listed in order of priority) are:

- **Socio-Economic Value**—an assessment of prospective societal and economic benefits e.g., public safety and health, national security, environmental quality, economic threats and opportunities, populations affected, and related factors. The basis of the assessment is an independent value/benefit analysis that estimates the extent of likely societal or economic value.

[7]ESE leadership consults with the Earth System Science and Applications Committee (ESSAAC) and considers national priorities identified by U.S. National Academy of Science in identifying candidate applications.

[8]ESE Research Strategy, 2001.

- **Application Feasibility—** an assessment of user readiness to adapt applications of Earth science and technology to operational environments. The time required to develop and implement an application is considered in the review. A threshold for application feasibility is the identification of a specific information mandate or discrete decision support system that benefits specifically from knowledge, data, and/or technology defined and proposed for development by an application.

- **Response to Oversight**—review of programs or projects that the Administration and/or Congress direct NASA to support with respect to ESE mission, goals and objectives. These sources of Executive or Congressional direction may include Executive Office of the President directives, legislation, regulation, budget requirements, and other official guidance (see Appendix B).

- **Appropriate for NASA**—the extent to which an application makes productive use of the unique or complementary assets and capabilities of NASA, and could not be performed as effectively by other government agencies or private entities.

- **Partnership Opportunity**—the extent to which applications can be carried out in collaboration with partners, especially U.S. Federal agencies. The objective of partnerships is to leverage resources and establish commitment by public and private partners to the effective transition of ESE results to operational uses.

- **Science and Technology Readiness**—the extent to which science and/or technology results can be developed to a level of maturity necessary to demonstrate operational use and that public and private institutions have the knowledge/technology infrastructure to adopt the application.

- **Program Balance—**the need to systematically balance the applications investment "portfolio" among application areas (e.g. community growth, environmental assessment) and among the types and levels of investment risk.

- **Cost / Budget Context**—the evaluation and analysis of costs, constraints and directions of the ESE with regard to available budgets and funding profiles. The Applications Program seeks to ensure that the financial risk of a project is acceptable and balanced with the potential for cost savings or improved user decision-making.

From the set of prioritized applications, NASA makes decisions on which applications to include in the investment portfolio for each fiscal year budget based on funding availability. NASA applies the same criteria (in reverse order, starting with Cost/Budget Context) to evaluate the capacity for the Program to conduct the prioritized applications.

2.3 Identification/Selection of Projects for Applications

In implementing individual applications, ESE establishes linkages between available science and technology capabilities and the specific application requirements. In order to define the linkages, NASA works with its partner(s) to develop a project plan describing a systematic approach of the necessary steps to demonstrate the viability of the application

for sustainable or operational use by a partnering organization. This stage identifies the appropriate approaches and organizations to fill the technical and/or business gaps identified in an application project plan. NASA addresses the requirements to fill the gaps with systems engineering support and solicitations for projects that provide opportunities for the public, academic, and private sector communities to contribute solutions. NASA reviews the project proposals received in response to the solicitations using the same priority criteria described above. NASA compiles documentation for all phases of the implementation of an application and makes the documentation of results and processes available for public benefits.

3.0 Concept of Operations

This section describes the concept of operations for implementing the Applications Program strategy to accomplish the vision and mission.

3.1 Program Management

The Applications Division at NASA Headquarters provides policy guidance and expertise in public/private partnerships, collaboration between Federal agencies and research institutions, research to operations transitions, and science and technology applications to meet national needs and goals. The Applications Division conducts program planning and analysis to identify and prioritize new target applications and to solicit, and select, new applications, projects and partners.

The Stennis Space Center serves as NASA's Lead Center for Earth Science Applications. It provides leadership and expertise to implement the Applications Program and leverages Agency resources in such areas as decision support systems, analytical and predictive modeling, data distribution and handling systems, remote sensing systems, standards, and interoperability. The Lead Center works with Applications Division at NASA Headquarters to develop the project plans for accomplishing priority applications. NASA develops solicitations, often in partnership with one or more Federal agencies, to provide opportunities for the public, academic and private sectors to compete to provide the applied research, products, and services required to accomplish the applications.

The Associate Administrator for Earth Science is responsible for the overall performance of the Applications Program, and his office reviews the Program routinely. The Associate Administrator periodically calls for an independent review by the National Research Council. The Earth System Science and Applications Committee (ESSAAC) reviews the Program on a semi-annual basis, using the performance evaluation points in Section 4 and the priority criteria identified in Section 2. The Office of Science and Technology Policy (OSTP) reviews the Program to assess its contributions to Administration priorities and the missions of other Federal agencies. The Office of Management and Budget (OMB) reviews the Program to assess its compliance with budgetary structure, accountability and the Administration's direction. Congress reviews the Program periodically on its performance in support of legislative branch priorities.

3.2 Program Framework

The Applications Program links together the elements of a "spatial information cycle."[9] As illustrated in Figure 2, this cycle includes phases that encompass NASA's role in remote sensing and the application of remote sensing data and products to decision-making.[10] Starting from the left side of the cycle in Figure 2 and moving counterclockwise, data are *tasked* and acquired from a variety of public and private sector **data measurement systems**, such as NASA's Earth Observing System (EOS) and commercial imaging systems, and *processed* to develop a set of **data products based on standards** for format and interoperability. The data products are then *exploited* by transforming remote sensing data and information into knowledge. **Data handling systems** enable effective *distribution* of data products and knowledge to decision-makers to get the right information to the right place at the right time. The NASA EOS Data Information System (EOSDIS) is an example of this phase of the cycle. Different organizations may manage different elements of the cycle. However, few organizations

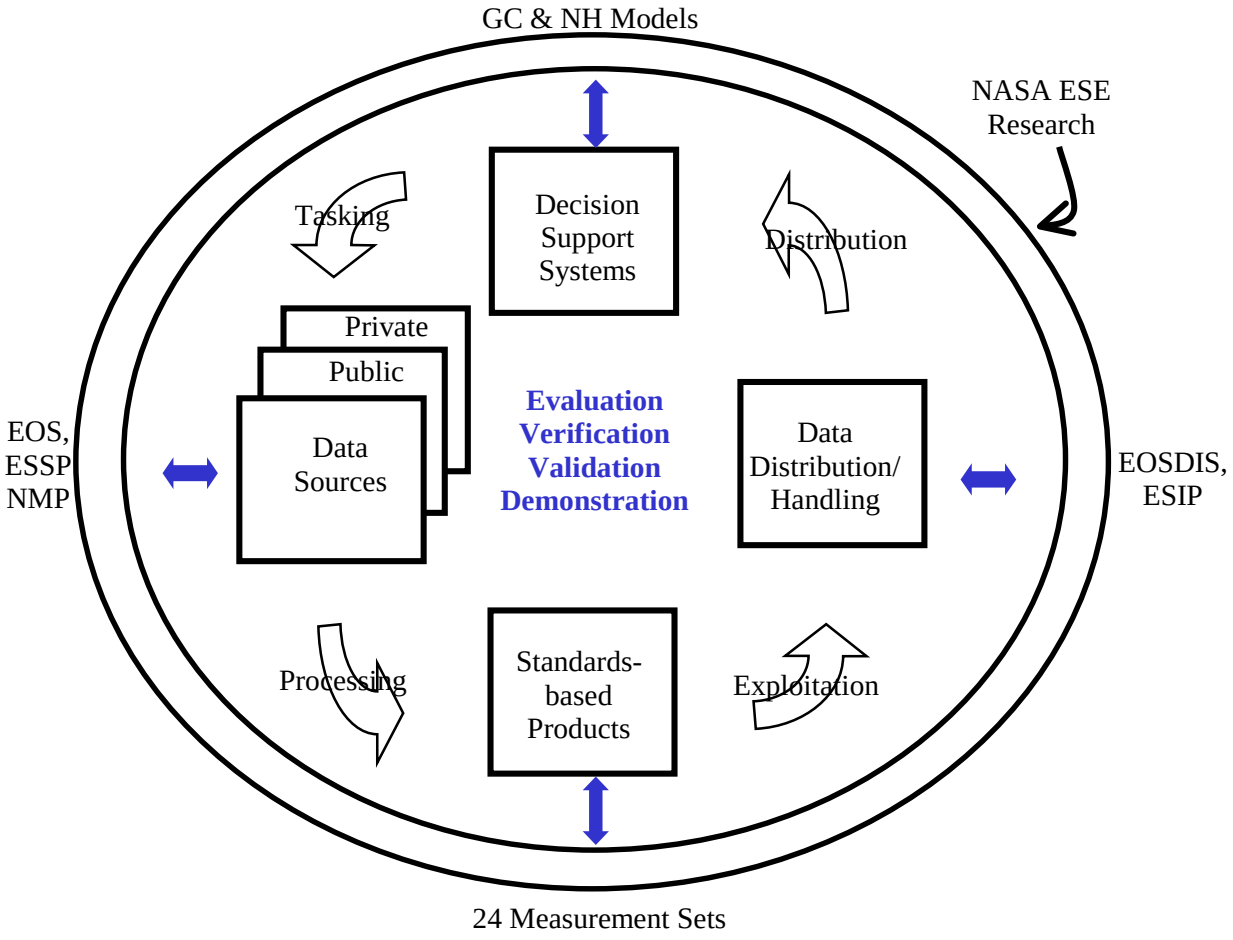

Figure 2 – Spatial Information Cycle

[9]NIMA refers to this cycle as TPED (tasking, processing, exploitation, and dissemination).
[10]NIMA and the United States Imagery and Geospatial Information System (USIGS) also use this cycle as the framework for their programs.

have the mandate to collaborate and integrate all of elements to support decision-making through to applications in **decision support systems**[11]. The Applications Program administers its program portfolio to bridge gaps between the elements in this cycle for applications in the national interest.

The Program also provides a bridge between the ESE's **research domain** and the **operational domain** of the public and private sectors. NASA is working the research domain of this cycle and has the benefit of administering all of the elements of the cycle within the ESE. NASA extends discrete research results (such as global land use land cover maps, EOSDIS capabilities, and predictive analysis of wildfire behavior) to applications enabling end-to-end solutions working with partners in all four of the elements. Going in the other direction, NASA evaluates discrete capabilities deployed in the operational domain (such as higher resolution remote sensing systems, high-bandwidth communications systems, and high-speed computers) for use in supporting Earth science research.

3.3 Program Implementation

Candidate applications projects pass through a rigorous selection process described in Section 2.0, and NASA evaluates them based on the metrics described in Section 4.0. The implementation component of the Program employs the functional steps of *applications research*, *verification and validation*, and *applications demonstration* in working to bridge the gaps from the research domain to the operational domain. Selected applications and related projects proceed through one or all of the following steps depending on maturity at the time of selection:

- *Applications Research*—evaluate the requirements for, and technical feasibility of, Earth science and remote sensing tools and methods for addressing national priorities for decision support in collaboration with partners.
- *Validation and Verification*—measure the performance characteristics of data, information, new tools, and/or methods to meet the requirements for a particular application.
- *Applications Demonstration*—work with partners to enable the adaptation and adoption of geospatial information tools and methods derived from ESE results to serve decision support in the national interest.

At the conclusion of a successful application extending the results of research to operational applications, NASA is no longer a source of funding. The desired outcome of applications projects is for the partner organization to use the resulting prototypes, processes, and documentation as benchmarks for operational use. The desired impact is for the application to thrive because the service provider and its customers derive value from the benefits of the operational use of Earth science in serving their decision-making processes.

[11] A decision support system (DSS) is an interactive computer-based system designed to help people and organizations retrieve, summarize, and analyze data and information and conduct predictive analysis on scenarios that enable enhanced capacity to make better decisions.

3.4 Program Actions

The key tactical elements of the Applications Program include the following:

- Participate regularly and substantively in relevant Federal agency and interagency mechanisms that identify, assess, and develop plans to meet national needs using geospatial knowledge and information.
- Act as a bridge between forums and organizations that represent the operational community and the NASA leadership.
- Conduct workshops, publish articles, and maintain Internet sites to provide the community (Federal, state, local, tribal, academic, and private sector) with access to current and relevant information about applications of Earth system science.
- Coordinate with the ESSAAC and other relevant groups to review program direction and application selections.
- Contribute to, and benefit from, NRC studies and reports, and other relevant compendiums of information on opportunities and approaches.
- Develop detailed roadmaps that describe the NASA science and technology capabilities in relation to societal, economic, technical, cost, timing and other factors identified as relevant to realizing national application priorities.
- Develop and maintain assessments of public and private sector Earth science and technology capabilities in catalogs that are readily accessible over the Internet.
- Sponsor science and technology assessments conducted by the National Research Council, as well as NASA-commissioned studies.
- In collaboration with the academic and research communities, and the public and private sectors, advance the state of knowledge and practice in measuring the value of applied geospatial knowledge and information.
- Issue competitive solicitations providing opportunities for the academic, public, and private sectors to contribute to realizing national applications.

4.0 Performance Evaluation

The Application Program performance evaluation applied to NASA-sponsored application projects is based on the Government Performance and Results Act (GPRA) of 1993 (P.L. 103-62). Congress enacted the GPRA to promote comprehensive performance management throughout the Federal departments and agencies. The Program performance evaluation focuses on program inputs and outputs, desired outcomes, and expected impacts associated with the activity to transition Earth science and remote sensing technologies research towards operational use by service provider organizations. The Applications Program draws its inputs from the results of on-going ESE investments in Earth science and remote sensing combined with capabilities offered by the private sector and other public sector sources. The Program outputs are prototypes, assessments, and/or procedures resulting from application demonstration projects. The Program outcomes are based on the extent to which the outputs are used as benchmarks for operational implementation on the national level. The Program impacts are socio-

economic gains in efficiency and effectiveness associated with the operational implementation of the application.

The following are representative inputs, outputs, outcomes, and impacts for the Applications Program:

Inputs:

- Earth system science results, models, algorithms, and "lessons learned"
- Remote sensing mission data and derived information products
- Private sector capabilities in data supply and value added services
- Capabilities provided through public/private partnerships
- Basic and applied research from academia and government labs
- Partners in Federal, state, local, tribal with their national needs for knowledge and information (e.g., energy forecasts, early warning systems for human health impacts, community disaster preparedness, weather and climate prediction for agriculture)
- Requirements for decision support associated with national to international geographic areas
- Interoperability standards

Outputs:

- Prototypes, benchmarks and/or guidelines documenting demonstrated solutions for national priority applications
- Documentation of results of verification and validation evaluations for Earth science and remote sensing solutions
- Publication of results of applications research on potential for Earth science and remote sensing technologies to serve specific applications in the national interest

Outcomes:

- Operational use of NASA enabled solutions in the Federal, state, local, tribal and industry sectors that result in societal and economic benefits in the United States
- New and expanded market opportunities for the private sector to supply goods and services
- Expanding and sustained opportunities for academia to conduct research on continuously improving capabilities
- More efficient and effective government
- Demonstration of industry competitiveness resulting in opportunities of supplying applications solutions nationally and internationally

Impacts:

- Accelerate the integration of research and development results into operational systems
- Increase the breadth and scope of market opportunities for the private sector in the market areas of remote sensing and related value-added services

- Increase the breadth and scope of the research opportunities for the academic sector in the areas of Earth science and remote sensing
- Recognition for enabling the United States to be preeminent in the field of remote sensing and Earth science solutions
- Realize the potential societal benefits and economic savings that result from effective use of critical information and knowledge (projected to be in the billions of dollars)

Put simply, the key evaluation of performance is the degree to which the Program supports organizations and people in the public and private sectors to routinely deliver and use Earth science information that saves lives, improves the quality of life, and saves resources through improved decision making.

NASA measures the ESE Application Program contribution to the NASA vision by assessing the degree to which effective applications of Earth science information *benefit the quality of life on Earth.*

5.0 Summary

This document describes the NASA ESE Applications Program's vision, mission, and goals for the ten-year period from 2002 through 2012. It defines a program planning strategy to accomplish the vision, addresses a concept of operations for implementing the strategy, and identifies performance measures to evaluate the Applications Program. As circumstances will likely change during the ten years of implementation, this document is intended to be a living one, sufficiently flexible to respond to changes in national policy and user needs, yet specific enough to provide guidance for applications projects and the overall program portfolio. The Applications Program welcomes comments regarding this document.

Appendix A - Program Glossary

Applications - specific use of results of science research, technology, data, information, knowledge, and/or modeling capability that serves a purpose.

Applied Research - research aimed at gaining the knowledge or understanding necessary to meet a specific, recognized need. (National Science Foundation)

Applications Demonstration - systematic approach to determine the viability of applying knowledge, data, and technology from research to meet operational requirements; implemented through the design and deployment of prototypes and processes in operational settings.

Assessments - *structured and systematic* appraisals of the state of science, technology, knowledge, and/or understanding of relevant capabilities, phenomena, or dynamics.

Benchmark- a standard or point of reference in measuring or judging quality, value, etc.

Decision Support System - an interactive computer-based system designed to help people and organizations retrieve, summarize, analyze data/information and conduct predictive analysis on scenarios that enable enhanced capacity to make better decisions.

Framework - basic description the relationships amongst elements in an operational environment that describes the mechanisms for how constituent technologies and institutional settings work together to meet a type of purpose.

Geospatial Data - information that identifies the geographic location and characteristics of natural or constructed features and boundaries of the Earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies. (USGS)

National Spatial Data Infrastructure - the technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and archive spatial data. (OMB)

Prototype - an initial scaled down or limited capacity version of a technique or system that is quickly developed to test the effectiveness of the overall design being used to solve a particular problem. It is sometimes termed ‘rapid prototyping’.

Roadmap - a system-level diagram depicting the progression of relevant science programs, technology developments and missions, and phases for an application related to a specific set of outputs and outcomes.

Standards - documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics to ensure that materials, products, processes or services are fit for their purposes. (OMB)

Stakeholders - organizations that have a vested interest in the Program including sources of requirements and beneficiaries of investments, products, processes and services. Primary stakeholder include representatives of the Executive and Legislative Branches, public sector representatives from Federal, state, local and tribal organizations, academic and research institutions, and the private sector.

Standards-based Data Products -packaged geospatial (geolocation referenced) data and information generated to meet documented performance specifications in compliance with national standards. Data products are generally produced to enable interoperability and are independently verified and validated.

Validation - the process of independently determining the effectiveness of a technology-based solution (usually a solution comprised of integrated technologies) to address a specific application.

Verification - the process of independently measuring the actual performance of a technology/system in terms of its own "advertised" performance parameters, and/or generally accepted performance parameters for the type of technology/system.

Appendix B – Program Directives

The ESE Applications Program is provided direction from the Executive Branch and mandates and funding from the Legislative Branch. Agreements with Federal, state, local, and tribal agencies, international organizations, and the private sector also contribute to the direction of the Program. The entries in this appendix are intended to be representative and are not exhaustive.

Executive Management Direction

The Applications Program receives direction from national directives and policies. Executive Management sources of direction include PDD/NSTC-8, PDD-23 and OMB Circular A-16 and review from the Office of Management and Budget.

Driver	Response
Presidential Decision Directive NSTC-8 provides guidance on the goals of the U.S. space program, and assigns responsibilities to agencies in various space sectors. There is specific reference to Earth science and remote sensing. This directive assigns NASA as the lead agency for research and development in civil space activities.	NASA, in coordination with other departments and agencies, focuses its research and development in Earth observation to better understand global change and the effect of natural and human influences on the environment.
Presidential Decision Directive-23 provides direction to support U.S. industry technology leadership and to contribute to technology innovation in the remote sensing marketplace.	NASA evaluates the potential for U.S. commercial remote sensing sources to address the requirements for standard information products that serve the national interest.
OMB Circular A-16 describes geospatial data as "a national capital asset". The Circular provides for improvements in spatial data coordination and for the use of geographic data for the benefit of the government and the Nation. Applications using spatial data that adhere to FGDC standards are identified to "enable cost effective public and private policy development, management and operations."	ESE Applications Program is represented on the Steering Committee and the Coordinating Committee for the Federal Geographic Data Committee. ESE provides applications research of candidate remote sensing technologies, through to verification and validation and applications demonstration in support of providing global data sets that are NSDI compliant.

Congressional Mandates

Driver	Response
Global Climate Change Act of 1990 has the objective of determining the origins, rates, and likely future course of national and anthropogenic changes.	ESE contributes evaluation, verification and validation, through to demonstration of remote sensing solutions from the public, private and foreign sectors to support global climate change research.
Commercial Space Act of 1998, and subsequent legislation, directs NASA to establish a long-term plan to promote scientific applications of U.S. commercial remote sensing capabilities through the purchase of data, development of applications, and collaboration with industry, research universities, and other government agencies.	NASA systematically evaluates the potential for private sector data and services to address information product needs that are in the national interest.

NASA Earth Science Enterprise Applications Strategy

NASA Guidance
NASA and the Earth Science Enterprise provide guidance to the Program in the form of Acts, Plans, and Agreements.

Driver	Response
National Aeronautics and Space Act endeavors to preserve the United States as a leader in aeronautical and space science and technology and in the applications thereof.	ESE contributes to preserving the US as a leader in this area by accelerating the connection between national priority needs for spatial information and Earth science solutions.
Earth Science Enterprise: ***Research Strategy*** provides scientific results to answer the science questions that are the underpinning of the applications program.	The Applications Program addresses the potential of specific research, including carbon cycle science, tropospheric winds, ocean color measurements, to meet applications needs in the national interest.

Agreements
The Agency, the Enterprise and the Lead Center for Applications have executed a number of formal agreements that link the Applications Program to important strategic commitments. These agreements provide specific sources of national and international level strategic and implementation guidance to the Program. They incorporate implementation options that include all levels of government, the private sector and the general public.

Driver	Response
Supply relevant remote sensing and related applied research, technology and development in exchange for requirements knowledge and insight into practice improvements **(USDA, USGS)**	NASA-USDA collaboration is carried out through implementation of a NASA Research Announcement (NRA) for Agriculture, Forest and Rangeland Management.
Conduct collaborative projects whenever they fulfill shared requirements, offer cost savings, increase agency capability, improve knowledge or improve environmental data and information **(NOAA Basic Agreement).**	Specific sub-agreements have been made between the agencies for the design, development, test and evaluation of the next generation of polar orbiting and geo-synchronous instruments and systems. The Program works with NOAA to determine an optimal means to fulfill shared application requirements.
Undertake cooperative calibration, validation and verification activities that benefit the nation in terms of public and commercial satellite and airborne sensor systems **(DOD, DOE, FEMA, NOAA, Scientific Data Purchase)**, and validate commercial remote sensing products and spatial information technologies for application to national transportation infrastructure development and constraints**. (DOT).**	ESE evaluates Scientific Data Purchase products and support the Joint Agency Commercial Imagery Evaluation (JACIE) group composed of NASA, Stennis Space Center, the National Imagery and Mapping Agency, the U.S. Geological Survey and selected academic institutions.
Collaborate on joint research and technology projects that meet the emerging geospatial information needs of the 21st Century. **(DOI, USGS)**	ESE supports research and technology requirements of USGS plan for ***The National Map***.

Appendix C - Representative Applications

The following are representative examples where ESE data and scientific processes have been and/or are being used to demonstrate solutions for decision support needs of other Federal Agencies, states, local communities, and/or industry applications.

A. Wild Fire Management
- Data source: NASA MODIS terrestrial and cloud mapping/monitoring data
- Data analysis: Calibration, processing, extraction of smoke signatures
- Information: Location and extent of smoke and fire
- Decision support: **USFS** and firefighter knowing the trend analyses of wildfire extent, expansion, and direction

B. Coastal Beach Mapping for Sustainable Management
- Data source: NASA airborne Wallops Test Facility lidar data
- Data analysis: Derivation of elevation data and change detection
- Information: Location and extent of beach morphology in coastal areas
- Decision support: **NOAA** and coastal community managers knowing the precise terrain for beach management

C. Agriculture Crop Greenness and Production Assessment
- Data source: NASA MODIS, AVHRR, LandSat
- Data analysis: Calibration, processing, extraction of crop signatures
- Model prediction: Crop greenness and production
- Information: Assessment of crop greenness and production
- Decision support: **USDA** and over 55,000 subscribers knowing the information provided in the Green Report® and RangeReport® products delivered by the Great Plains RESAC.

D. Hurricane Track Prediction
- Data source: NASA QuickScat
- Data analysis: Calibration, processing, verification and validation
- Model prediction: Global wind profiles
- Information: 24-hour forecasts of global wind profiles
- Decision support: **NOAA National Weather Service** daily delivery of weather products

E. Aviation Safety through Synthetic Vision Systems
- Data sources: NASA Science Data Purchase project: commercial digital elevation model (DEM) data products
- Data analysis: Verification and validation of high-resolution DEM products
- Model prediction: Terrain visualization
- Information: Location and extent of terrain and land features
- Decision support: **FAA** and aviation community support through real-time visualization of terrain in limited visibility situations

Appendix D - References

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