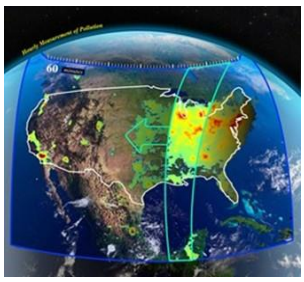
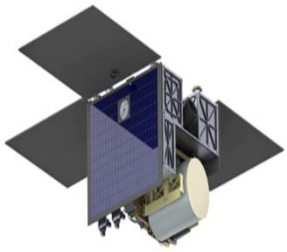
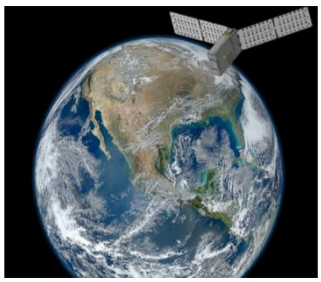
NASA
Office of Inspector General

NASA's Earth System Science Pathfinder Program

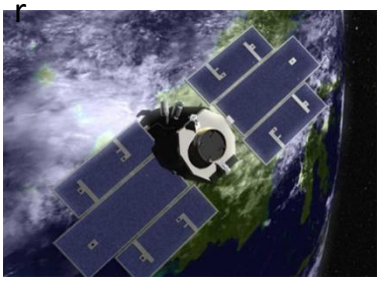


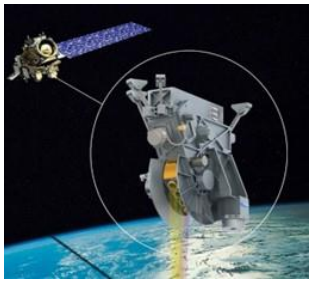


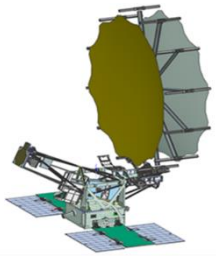


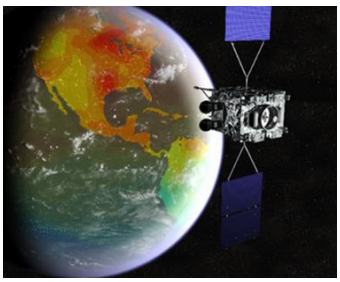








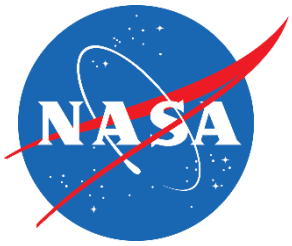








September 5, 2023 **IG-23-018**



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RESULTS IN BRIEF

NASA's Earth System Science Pathfinder Program

September 5, 2023 IG-23-018 (A-22-13-00-SARD)

WHY WE PERFORMED THIS AUDIT

Earth's climate is changing—the average surface temperature in 2022 was tied for the fifth warmest year on record. In addition, extreme weather events are increasing, with 29 billion-dollar-plus events in 2022—18 of which were in the United States. NASA's Earth System Science Pathfinder (ESSP) Program was established in 1996 to stimulate new scientific understanding of the global Earth system to meet the challenges of climate change and other environmental events such as forest fires and floods by funding small, rapid-development missions. In 2009, NASA introduced the ESSP Earth Venture Class to create low-cost missions focused on developing innovative research and higher risk technologies that ultimately can help communities respond to the changing environment. With an annual budget of $236 million, ESSP currently supports 22 active projects. Through the development of orbital and suborbital remote-sensing instruments, these projects produce data to address key Earth science research questions concerning the atmosphere, oceans, land surface, polar ice regions, and solid Earth.

In this audit we assessed NASA's management of the ESSP Program to determine whether the Program is (1) providing periodic opportunities for developing Earth Venture Class projects, (2) controlling mission and project costs and meeting milestones within established NASA risk and technical standards, and (3) collecting science data that advances NASA's Earth system science and climate research. To complete this work, we reviewed federal and NASA criteria, policies, and procedures, and evaluated documents, plans, and directives related to the ESSP solicitation and selection process, unlaunched projects, and project applications for societal benefits. We also interviewed NASA officials, Principal Investigators (PI), and project subcontractors and conducted a survey of PIs and Deputy PIs.

WHAT WE FOUND

With Earth Venture Class missions, NASA issues solicitations for science investigations and competitively selects projects led by a PI who may work at an educational institution, in private industry, at a not-for-profit organization, or NASA Center. PIs are accountable to NASA for overall mission success including meeting cost and schedule milestones. We found NASA provided frequent solicitations for science investigations to advance Earth science research through its Earth Venture Class missions; however, we identified major weaknesses with project management, mission design and operations, and instrument development in several selected projects. Additionally, NASA did not adequately vet PIs during the solicitation phase to ensure they have appropriate project management and contracting experience as well as sufficient time dedicated to adequately manage their projects. Involving the ESSP Program Office (ESSPPO)—responsible for the management, direction, and implementation of Earth Venture Class missions—earlier in the solicitation and evaluation process may have mitigated some of these issues. We also found that NASA provided PIs inconsistent and unclear expectations on project reporting requirements during the solicitation process. Moreover, four Earth Venture Class projects solicited as Class D missions believed they were being treated as Class C, which require additional project reporting, causing uncertainty among PIs about NASA's expectations.

While the ESSP Program has controlled cost growth and met milestones for 18 of its 22 active projects, as of May 2023 the remaining four of seven unlaunched projects face cost and schedule challenges primarily related to subcontractor disruptions, access to space costs, and limited experience of PIs managing projects. For example, before it was canceled the Geostationary Carbon Cycle Observatory (GeoCarb) project faced cost growth and schedule delays because the

subcontractor underestimated the work required to complete the instrument within the project's cost cap and experienced poor work performance and staffing issues during instrument development. The Geosynchronous Littoral Imaging and Monitoring Radiometer (GLIMR) project is experiencing similar issues managing its subcontractor, leading to cost overruns and delays that may impact the PI's ability to complete the project within the cost cap. We found that university-based PIs, like the ones for both GeoCarb and GLIMR, often do not have the previous project management experience needed to effectively manage large subcontractors and have struggled to manage their ESSP projects due to their unfamiliarity with NASA procedures. Further, we believe the contract and project management guidance NASA provides PIs is insufficient and it is in the Agency's best interest to ensure PIs have adequate contract and project management training or experience to successfully manage these projects.

Finally, we found Earth Venture Class projects are making progress incorporating more societal applications, as exemplified with Multi-Angle Imager for Aerosols; however, this mission was the first Earth Venture Class project to be selected that incorporated an application as an essential part of its proposal. We found the comprehensive incorporation of societal applications remains secondary and under-realized. In addition, requirements for societal applications are loosely required, poorly understood by proposers, and nominally considered during the selection process. Further, the Agency lacks a common approach to incorporating applications and although ESSPPO set aside $850,000 to fund small application activities, the funds are time-limited and will lapse in 2023. NASA has not provided PIs nor Science Mission Directorate personnel with clear guidance regarding the value and expectations for societal applications, likely resulting in diminished returns on investment and missed opportunities to provide critical societal benefits.

WHAT WE RECOMMENDED

To improve NASA's management of its ESSP Program, we recommended the Associate Administrator for Science Mission Directorate (1) develop an improved methodology to ensure subject matter expertise from the ESSP Program is better incorporated during the AO process to help mitigate technical, cost, and schedule risks while averting conflicts of interest; (2) reexamine its selection process to ensure PIs or their teams have sufficient experience, including project management, and the ability to dedicate necessary resources to effectively manage ESSP projects; (3) reissue and require Science Mission Directorate stakeholders to follow the tenets of the 2017 decision memorandum on Class D missions; (4) in collaboration with NASA's Launch Services Program, develop a process to engage early and evaluate alternative launch options in the event that ESSP projects encounter access to space issues; (5) conduct a lessons learned review of the GeoCarb mission to identify what NASA, PI, and contractor practices and activities should be revised and applied to the management of future Earth Venture Class projects; (6) develop a plan to provide PIs and their teams with contract and project management training post-selection approval to better equip them to manage subcontractors; (7) develop formal and clear guidance on the roles, responsibilities, and expectations for the inclusion of applications within Earth Venture Class projects; and (8) develop a methodology for funding applications in Earth Venture Class projects.

We provided a draft of this report to NASA management who did not concur with recommendation 1 and concurred or partially concurred with recommendations 2 through 8. Regarding recommendation 1, after further discussions with Agency management, we concluded that their actions are well-informed and meet the intent of the recommendation; therefore, the recommendation is resolved and closed. We also consider management's comments to recommendations 2 through 8 responsive and those recommendations are resolved and will be closed upon completion and verification of the corrective action.

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Acronyms

ABC	Agency Baseline Commitment
AO	Announcement of Opportunity
CYGNSS	Cyclone Global Navigation Satellite System
ECOSTRESS	Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station
ESD	Earth Science Division
ESSP	Earth System Science Pathfinder
ESSPPO	ESSP Program Office
EVC	Earth Venture Continuity
EVI	Earth Venture Instrument
EVM	Earth Venture Mission
EVS	Earth Venture Suborbital
GeoCarb	Geostationary Carbon Cycle Observatory
GLIMR	Geosynchronous Littoral Imaging and Monitoring Radiometer
INCUS	Investigation of Convective Updrafts
KDP	Key Decision Point
MAIA	Multi-Angle Imager for Aerosols
NPR	NASA Procedural Requirements
OIG	Office of Inspector General
PAL	Program Applications Lead
PI	Principal Investigator
PREFIRE	Polar Radiant Energy in the Far Infrared Experiment
ROSES	Research Opportunities in Space and Earth Science
SOMA	Science Office for Mission Assessments
SMD	Science Mission Directorate
TROPICS	Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats

INTRODUCTION

Earth's climate is changing—the average surface temperature in 2022 was tied for the fifth warmest on record, with the nine most recent years being the warmest since modern record keeping began. Along with increases in temperature, other changes in the Earth climate system include declines in Arctic Sea ice and increases in extreme weather events. In 2022, the world was impacted by 29 billion-dollar-plus weather disaster events—18 in the United States alone. This includes $113 billion in damages from Hurricane Ian in September 2022, the third most costly hurricane in U.S. history; a $20 billion drought and heat wave in Europe that killed more than 16,000 people; and deadly floods in Pakistan that resulted in nearly 1,700 deaths.

NASA's climate mission is to observe, better understand, and address climate change through science, exploration, and innovation. In January 2021 NASA joined the first National Climate Task Force, created by the President to mobililize more than 25 federal agencies to work together to set a series of ambitious climate goals.[1] Subsequently, in March 2023 NASA released its first Climate Strategy, which evaluated NASA's Earth science portfolio and identified priorities to achieve the Agency's climate mission of increasing our understanding of the Earth and its climate.[2] The ability to view Earth from the unique vantage point of space through multiple Earth-observing satellites provides a broad and integrated set of uniformly high-quality data covering the entire planet. This data helps inform decision-makers across all levels of government as well as in industry, the disaster prevention and response field, and agriculture to make policy and operational decisions.

NASA's Earth System Science Pathfinder (ESSP) Program leverages competitively selected Earth science research opportunities that accommodate new and emerging scientific priorities and measurement capabilities. The Program plays a vital role by funding relatively inexpensive science instruments and missions that seek to produce accurate and timely information on our most pressing climate concerns such as addressing sea level rise and combatting geological hazards and disasters like earthquakes, landslides, and hurricanes.

In this audit, we assessed NASA's management of the ESSP Program. Specifically, we evaluated whether the Program is (1) providing frequent periodic opportunities for developing Earth Venture Class projects, (2) effectively controlling mission and project costs and meeting milestones within established NASA risk and technical standards, and (3) collecting science data that advances NASA's Earth system science and climate research. Details of the audit's scope and methodology are outlined in Appendix A.

Background

Within NASA's Science Mission Directorate (SMD), the Earth Science Division's (ESD) ESSP Program strives to stimulate new scientific understanding of the global Earth system to meet the challenges of

[1] The White House, *Executive Order on Tackling the Climate Crisis at Home and Abroad* (January 27, 2021).

[2] NASA NP-2023-03-3112-HQ, *Advancing NASA's Climate Strategy* (March 29, 2023).

climate change and other environmental events such as forest fires, heat waves, floods, and storms.[3] The ESSP Program was established in 1996 to address emerging areas of science not addressed by ESD's Earth Observing System through existing technologies using a series of small, rapid-development missions.[4] Over time, the Program expanded its goals and objectives following recommendations from multiple Decadal Surveys.[5] In 2009, NASA introduced the ESSP Earth Venture Class in response to the 2007 Decadal Survey recommendation to create low-cost Earth science research and application missions focused on developing innovative ideas and higher risk technologies and provide training for future leaders of space-based observations for Earth science applications.[6] Addressing a 2017 Decadal Survey recommendation, NASA added the Earth Venture Continuity (EVC) component to the Earth Venture Class to provide opportunities for low-cost sustained observations.[7]

NASA encourages Earth science research through the Earth Venture Class missions by issuing solicitations for science investigations. Projects are then competitively selected and led by a Principal Investigator (PI) who may work at an educational institution, in private industry, at a not-for-profit organization, or NASA Center. PIs are given end-to-end mission responsibility and are accountable to NASA for overall mission success, to include meeting cost and schedule milestones. While these projects have individual science objectives, mission requirements, and technical interdependencies, all of them operate under specific cost and schedule constraints and are supported by the ESSP Program through a common funding and management structure.

The ESSP Program Office (ESSPPO) is responsible for the management, direction, and implementation of the Earth Venture Class missions. The office's Program Manager is responsible for the overall management of ESSP as well as implementation of selected projects. Working closely with the PIs, Mission Managers are responsible for the programmatic oversight of specific projects, ensuring they are implemented properly and supported adequately.

[3] The global Earth system is made up of multiple interrelated subsystems that work together to keep the planet in balance. These subsystems are (1) the atmosphere, a thin layer composed of a mixture of gases and particles suspended in the air that surround the Earth, including carbon dioxide and water; (2) the hydrosphere, which includes the liquid ocean, inland water bodies, and groundwater; (3) the cryosphere, a subset of the hydrosphere that consists of frozen water; (4) the geosphere, which includes the solid Earth—the core, mantle, crust, and soil layers; and (5) the biosphere, which includes all of Earth's organisms, such as humans and matter that has not yet decomposed.

[4] The Earth Observing System provides an improved understanding of the Earth as an integrated system through a coordinated series of polar-orbiting and low inclination satellites that enable long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans.

[5] The Decadal Survey is a report prepared by the National Academies of Sciences, Engineering, and Medicine (formerly the National Research Council). NASA asks the National Academies once each decade to project 10 or more years into the future and prioritize research areas, observations, and notional missions. National Research Council, 2007 to 2017, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (2007) and National Academies, 2017 to 2027, *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space* (2018).

[6] An application of science is any use of scientific knowledge for a specific purpose with practical and societal benefits.

[7] EVC projects are intended to develop innovative approaches to acquiring existing measurements at a lower cost. For example, Libera, the first project selected under the EVC component, intends to build a novel cost-effective instrument that introduces new technologies such as advanced detectors to improve the data NASA collects on solar radiation reflected by the Earth. This instrument will enable new science and maintain the decades-long climate data record from NASA's suite of Clouds and the Earth's Radiant Energy System instruments.

With an annual budget of $236 million and a staff of 18 employees, the Program currently supports 22 active projects.[8] In turn, each of these projects support ESSP's overarching goal through the development and operation of orbital and suborbital remote-sensing instruments that produce data that can be utilized to address key Earth science research questions concerning the atmosphere, oceans, land surface, polar ice regions, and solid Earth.[9]

ESSP Earth Venture Class projects are divided into four mission categories: Earth Venture Suborbital (EVS), Earth Venture Instrument (EVI), Earth Venture Mission (EVM), and Earth Venture Continuity or EVC.[10]

- EVS projects are 5-year suborbital and airborne investigations with a cost cap of either $15 million or $30 million per selection. EVS solicitations are released every 4 years, and multiple investigations may be selected from each solicitation. NASA provides access to deployment sites for EVS projects.
- EVI projects are space-borne instruments developed in less than 5 years for flight on a NASA-arranged host spacecraft. EVI projects have a cost cap of $112 million per solicitation for development and operations and are solicited every 3 years. Multiple EVIs can be selected for each solicitation subject to the overall cost cap. Costs associated with access to space are covered by NASA for EVI projects.
- EVM projects are complete self-contained missions developed over a 5-year period with 2-year operations mission timelines. EVM projects have a cost cap of $193 million per solicitation and are solicited every 4 years. The PI may elect to use NASA-provided launch services, the cost of which will be subtracted from the cost cap.
- EVC projects are space-borne instruments or missions designed to lower costs for the long-term acquisition of significant EVC observations.[11] EVC projects have a cost cap of $173 million per solicitation and are solicited every 3 years. Costs associated with access to space are covered by NASA for EVC projects.

Table 1 summarizes the four Earth Venture Class mission categories.[12]

[8] Of the 22 active projects, Geostationary Carbon Cycle Observatory (GeoCarb) was canceled in November 2022; however, closeout activities were ongoing as of May 2023.

[9] A remote-sensing instrument, such as a camera on a satellite or aircraft, can detect and monitor the physical characteristics of an area on Earth by measuring its reflected and emitted radiation. Orbital missions achieve enough speed to remain in orbit around Earth. Suborbital missions do not achieve enough speed to enter orbit and instead return to Earth before completing an orbit. NASA's Earth science goals guide ESD's selection of investigations and include atmospheric composition, weather, carbon cycle and ecosystems, water and energy cycle, climate variability and change, Earth surface and interior, and societal benefit.

[10] Earth Venture Class missions make up 18 of ESSP's 22 active projects. The 4 non-Earth Venture Class missions are Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), CloudSat, Orbiting Carbon Observatory-2 (OCO-2), and Orbiting Carbon Observatory-3 (OCO-3).

[11] EVC missions focus on demonstrating innovative, low-cost approaches to maintaining targeted measurements important to the Earth science community in an unbroken and consistent way. The National Academies' 2017 Decadal Survey recommended this new way to continue existing measurements of vital importance over the long term.

[12] The cost caps provided are current as of May 2023; however, the cost caps can vary.

Table 1: NASA ESSP Earth Venture Class Mission Categories (as of May 2023)

Category	Risk Classification	Number of Active Projects	Solicitation Cycle	Cost Cap
Earth Venture Suborbital (EVS)	N/A[a]	5	48 months	$30 million[b]
Earth Venture Instrument (EVI)	Class C or D	9	36 months	$112 million
Earth Venture Mission (EVM)	Class D	3	48 months	$193 million
Earth Venture Continuity (EVC)	Class C	1	36 months	$173 million

Source: NASA Office of Inspector General (OIG) presentation of Agency data.

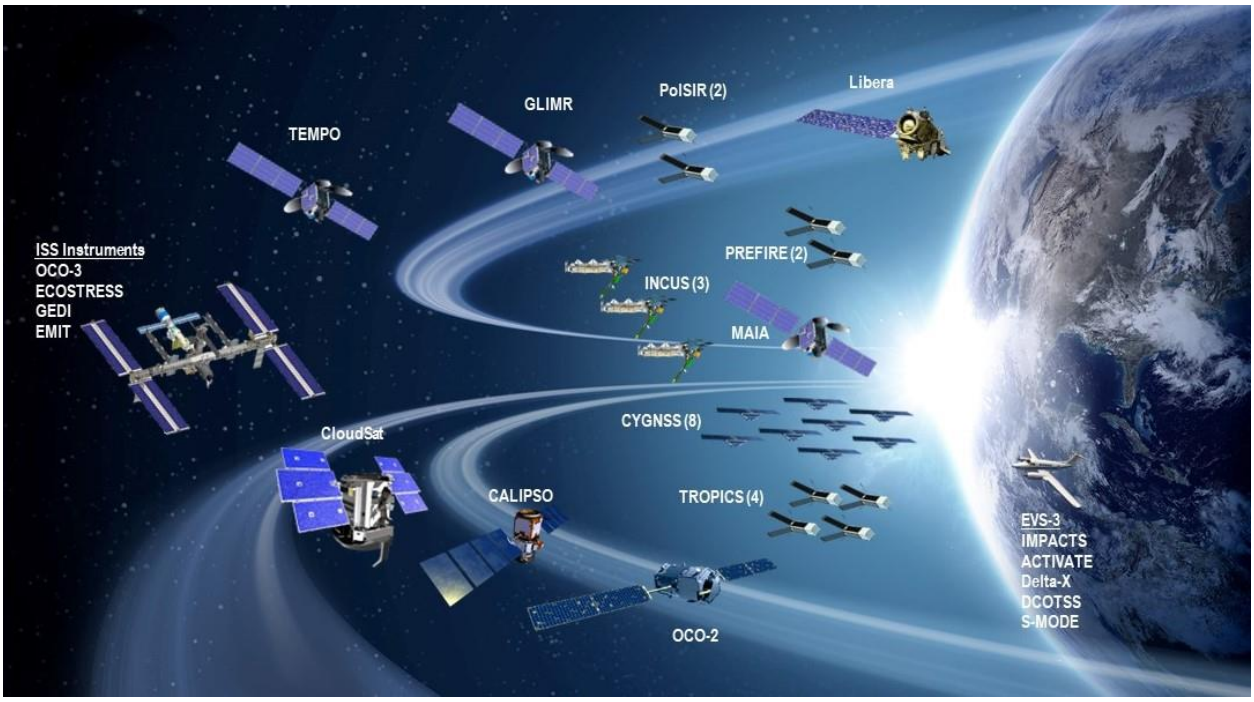
[a] EVS projects are solicited under Research Opportunities in Space and Earth Science, which do not follow NASA Procedural Requirements (NPR) 7120.5F and do not have risk classifications.
[b] EVS projects are individually cost capped at either $15 million or $30 million and multiple investigations may be selected.

NASA has four risk classification considerations for its mission and instrument projects: Classes A through D. SMD's Associate Administrator determines whether Earth Venture Class projects are Class C or D. Class C missions have a moderate risk tolerance driven by technical objectives that normally represent a medium priority mission with medium complexity. Class D missions have a high risk tolerance driven by programmatic constraints and normally represent a lower priority mission with medium to low complexity. Class A and B missions have lower risk tolerance levels with higher mission priorities and complexities, which are often NASA's most expensive and complex projects.

Notably, ESSP's relatively inexpensive missions allow NASA to respond to developments in research capabilities and environmental issues more efficiently than in the past when the Agency would instead seek to develop a major Earth science satellite mission.[13] Figure 1 shows ESSP's current projects.

[13] Compared to other NASA projects, ESSP projects are inexpensive due to their lower cost caps. NASA defines major programs and projects as those with life-cycle costs of at least $250 million. Comparatively, ESSP projects are capped at approximately 23 to 55 percent less than the major programs and projects threshold of $250 million.

Figure 1: NASA ESSP Portfolio of Missions and Instruments (as of May 2023)



Source: NASA.

Note: Although Geostationary Carbon Cycle Observatory (GeoCarb) is currently considered an active project as closeout activities remain ongoing, it was canceled in November 2022 and therefore is not shown in this figure.

Selection Process for Earth Venture Class Projects

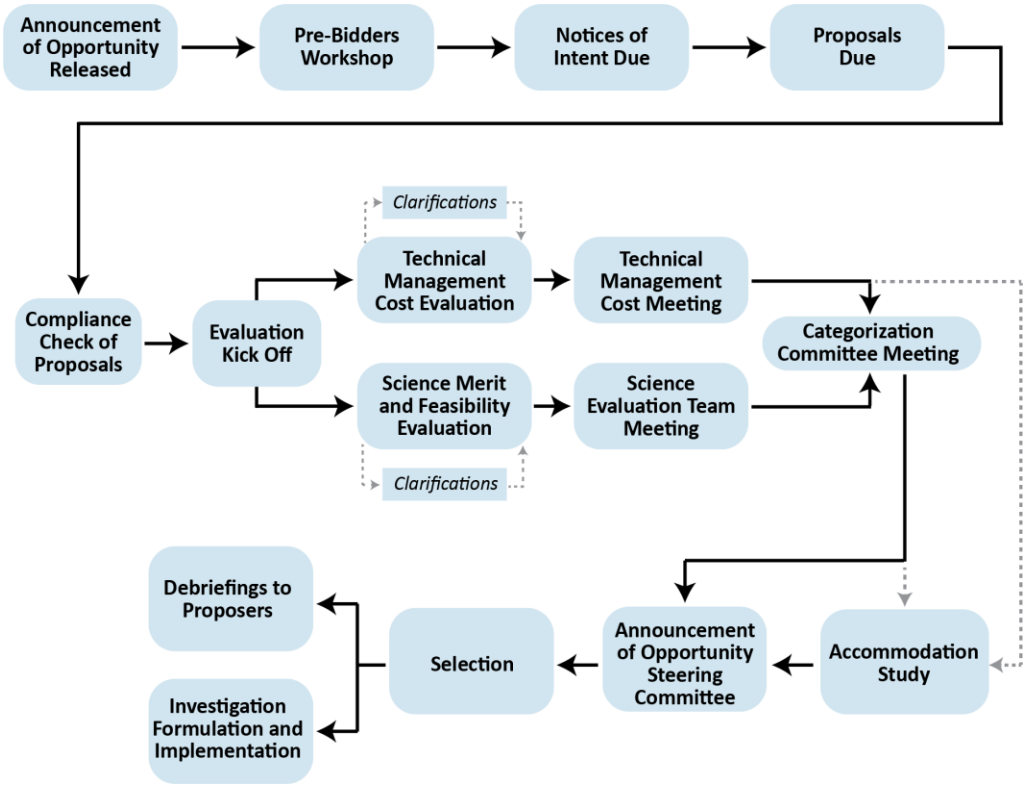
While ESSPPO provides oversight for the Earth Venture Class projects, the solicitation, evaluation, and selection of these projects is conducted by SMD at NASA Headquarters; Program personnel are not involved in these processes to avoid any potential conflicts of interest. The choice of solicitation vehicle depends on the category of the project. EVI, EVM, and EVC use the Announcement of Opportunity (AO) process while EVS uses the Research Opportunities in Space and Earth Science (ROSES) process.[14] For ROSES, the type of award, grant, or cooperative agreement depends on NASA's role in the performance of the award.

Under the AO solicitation, program scientists in SMD's ESD manage the overall process and use two independent review panels composed of non-NASA subject matter experts to peer review and evaluate the proposals. One panel focuses on evaluating the proposed science while the other panel assesses the technical, management, and cost risks of the proposals. The Associate Administrator for SMD makes the final selection on the proposals submitted by prospective PIs. ESSPPO is notified at the same time NASA publicly announces the selected proposals. The Science Office for Mission Assessments (SOMA)

[14] NASA funds research and technology development through multiple solicitation processes. AO is a type of Broad Agency Announcement used to solicit science investigations that require a space flight mission. AOs result in the award of contracts and deliverables including spacecraft, instruments, data, and science results published in journals. ROSES is the primary omnibus solicitation for research, which is made up of different calls for proposals—each with its own topic and due date—and is conducted annually using a competitive, peer review process.

provides a transition package to ESSPPO, which includes a detailed evaluation of the selected proposals and identifies technical, management, and cost risks.[15] Figure 2 provides an overview of NASA's AO project selection process.

Figure 2: NASA's Announcement of Opportunity Project Selection Process (as of May 2023)



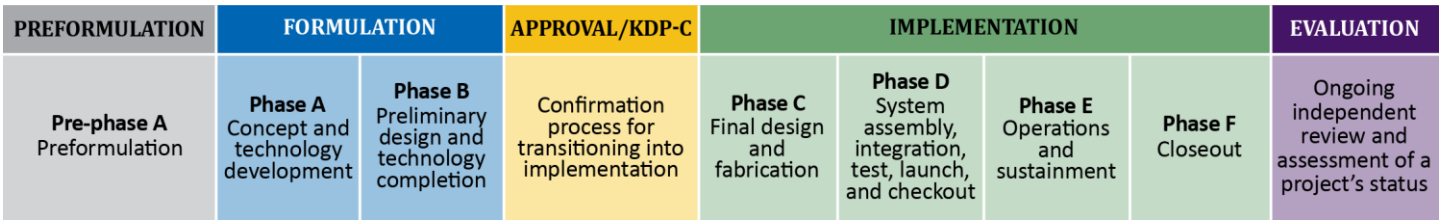
Source: NASA OIG presentation of Agency data.

Project Life Cycle and Current Status of ESSP Projects

ESSP projects are divided into two primary phases: Formulation and Implementation. These are further divided into Phases A through F, with Phases A and B falling under Formulation and C through F under Implementation. Each project phase is preceded by a Key Decision Point (KDP), which determines whether a project is ready to proceed from one phase to the next. For example, KDP-C determines whether a project is prepared to move into Phase C (final design and fabrication). Each phase also includes reviews to ensure that project requirements are met and work is completed within the project's parameters. These include the Preliminary Design Review (Phase B), which determines if a project has met Phase B's requirements and is ready to begin Phase C work, and the later System Integration Review (Phase C), which assesses if a project is prepared to move into Phase D. Figure 3 illustrates NASA's project life cycle.

[15] SOMA supports SMD in the acquisition of Earth and space science missions and instruments through the development of AO solicitations and the technical, management, and cost evaluations of proposals received in response to the AO solicitations and Phase A concept studies. In addition, SOMA leads special studies, independent assessments, and reviews for SMD.

Figure 3: NASA Project Life Cycle



Source: NPR 7120.5F.

Immediately after selection, the Formulation Phase involves coordination between the program, project, and Technical Authority to determine and document any tailoring of NASA requirements to successfully meet mission requirements.[16] Following this, projects proceed to the Approval for Implementation, during which NASA makes a commitment to Congress and the Office of Management and Budget regarding the cost and schedule of the mission. The Implementation Phase includes the construction, integration and test, launch or deployment, and operations where the project's focus shifts toward maintenance and data analysis.

Currently, the ESSP Program supports 22 projects in various stages of development, operations, and closeout. Table 2 shows the current ESSP portfolio of projects, including current phase, launch or anticipated launch date, and project costs as of May 2023. See Appendix B for a more detailed description of these projects.

[16] The Technical Authority—from the institutional organizations of Engineering, Safety and Mission Assurance, and Health and Medical—is funded independently of programs and projects and plays a vital role in NASA's system of checks and balances by providing independent oversight of program and project activities in support of safety and mission success. The Technical Authority also approves changes and waivers to all Technical Authority requirements. Program and Project Managers remain responsible for the safe conduct and successful outcome of their programs and projects in conformance with governing requirements.

Table 2: NASA ESSP Portfolio Project Summary (as of May 2023)

Project	Launch Date/ Planned Launch Date	Project Costs as of May 2023
Formulation Phase		
Geosynchronous Littoral Imaging and Monitoring Radiometer (GLIMR)	TBD	$50.9 million
Investigation of Convective Updrafts (INCUS)	August 2026	$16.3 million
Polarized Submillimeter Ice-cloud Radiometer (PolSIR)	2027	$0
Implementation Phase		
Libera	January 2027	$44 million
Multi-Angle Imager for Aerosols (MAIA)	November 2025	$124.8 million
Polar Radiant Energy in the Far Infrared Experiment (PREFIRE)	August 2024	$35.6 million
Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats (TROPICS)	May 8 and 26, 2023	$51 million
Tropospheric Emissions: Monitoring of Pollution (TEMPO)	April 7, 2023	$187.2 million
Operations Phase		
Aerosol Cloud Meteorology Interactions over the Western Atlantic Experiment (ACTIVATE)	Deployments Complete[a]	$23.2 million
Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO)	April 28, 2006	$123.8 million
CloudSat	April 28, 2006	$145.8 million
Cyclone Global Navigation Satellite System (CYGNSS)	December 15, 2016	$182.7 million
Delta-X	Deployments Complete[a]	$12.3 million
Dynamics and Chemistry of the Summer Stratosphere (DCOTSS)	Deployments Complete[a]	$22.4 million
Earth Surface Mineral Dust Source Investigation (EMIT)	July 14, 2022	$110.9 million
Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)	June 29, 2018	$66.1 million
Global Ecosystem Dynamics Investigation (GEDI)	December 5, 2018	$127.7 million
Investigation of Microphysics and Precipitation for Atlantic Coast Threatening Snowstorms (IMPACTS)	Deployments Complete[a]	$21.3 million
Orbiting Carbon Observatory-2 (OCO-2)	July 2, 2014	$471.6 million
Orbiting Carbon Observatory-3 (OCO-3)	May 4, 2019	$105.8 million
Sub-Mesoscale Ocean Dynamics Experiment (S-MODE)	Deployments Active[a]	$17.7 million
Canceled		
Geostationary Carbon Cycle Observatory (GeoCarb)	Canceled	$170.4 million

Source: NASA OIG presentation of Agency information.

[a] A deployment occurs when a spacecraft or instrument is moved out of the launch vehicle and into the correct orbit or trajectory. Based on the mission, an Earth Venture Class spacecraft or instrument can be deployed multiple times over the life cycle of the mission. A deployment associated with an EVS project refers to one of the field deployments (typically aircraft or ship) that constitute the operations phase for these suborbital projects.

Critical Factors to Earth Venture Class Project Success

In addition to meeting technical, cost, and schedule requirements, access to space coupled with societal applications are critical factors to the success and impact of Earth Venture Class projects. Reliable and affordable access to space is essential to minimize cost growth and schedule delays. Further, selection and development of science investigations with direct societal applications that can be used to meet current challenges and help communities around the world respond to our changing environment is critical to project relevance and taxpayer return on investment.

Access to Space

Viable access to space is a major challenge for some ESSP projects due to complex logistics and high costs. Access to space is an umbrella term that broadly refers to the ability to get a project to space, sustain its presence, and use space technologies and data. For purposes of this audit, we define access to space specifically as the ability to transport the instrument and/or spacecraft to space and involves launch vehicles, providers, and infrastructure. Logistically, access to space is impacted by limited launch providers with schedule and payload limitations. To maximize the availability of launches, providers may offer rideshare opportunities, which allow the launch vehicles to carry secondary payloads in addition to primary payloads. While secondary payloads may have this opportunity "to hitch a ride," they must meet schedule and payload limitations as well as not interfere with the primary payload. Although technological advancements and private market vendor expansion have lowered costs, getting to space remains an expensive endeavor.

With EVI and EVC projects, NASA is required to provide and pay for launch support services—the cost of which is not part of the project's cost cap. However, EVM projects are responsible for coordinating logistics and including funding for access to space in their individual budgets. EVM projects can elect to have NASA procure their launch vehicle during the proposal phase and the cost is subtracted from their cost cap. NASA's Launch Services Program is responsible for supporting access to space for ESSP projects. With limited providers, ESSP projects must remain on schedule and within payload constraints or risk losing their launch opportunity.

Societal Applications

Science asks big theoretical questions like "why or how" while applications ask practical questions like "how can this information help?" An application of science is any use of scientific knowledge for a specific purpose that results in practical and societal benefits. In addition, applications can have economic and societal impacts. For example, while data collected on sea level rise provides information on our changing environment, the same data can also be used by communities to better prepare coastal protections. Another example is data collected on evapotranspiration, the process through which water leaves plants, soils, and other surfaces and returns to the atmosphere. Not only does this data increase our

Collection of Evapotranspiration Data

A research scientist with the NASA Ames Cooperative for Research in Earth Science and Technology adjusts a scientific instrument designed to support evapotranspiration data collection.

Source: NASA.

understanding of the Earth's water cycle, but it is also used by farmers to plan more efficient and economical crop watering as well as help rural communities design more sustainable water conservation programs. Applications are widely recognized as a central and vital element of science, especially Earth science. Both Congress and the National Academies encourage NASA to ensure its projects deliver practical benefits, particularly within its Earth science missions and programs. The 2017 Decadal Survey noted, "Earth Science is special in the extent and breadth of its practical benefits to society." It further detailed the critical need for societal applications and recommendations for bridging the existing gap within Earth science.

NASA Needs to Improve Its Solicitation, Evaluation, and Selection of Earth Venture Class Projects

While NASA consistently provides periodic opportunities to innovatively advance Earth science research through its Earth Venture Class missions, the Agency can improve its solicitation, evaluation, and selection process to help the ESSP Program manage its projects. Specifically, subject matter experts from ESSPPO should be consulted during the solicitation and evaluation process to help identify major weaknesses in proposals under consideration. NASA can also improve its processes to better assess project management, mission design and operations, and instrument development risks during the selection process for EVI and EVM projects.[17]

NASA Solicits Earth Venture Class Projects on a Regular Cadence

Since the establishment of the Earth Venture Class within the ESSP Program in 2009, NASA has successfully provided periodic opportunities for orbital and suborbital projects to innovatively advance Earth science research. For the most part, NASA has adhered to the cost caps and schedule constraints required for Earth Venture Class projects to ensure availability of funding for regular and frequent solicitations. NASA uses the Announcement of Opportunity (AO) single-step proposal process to solicit EVI and EVM projects.[18] We found that NASA adheres to structured evaluation criteria that appropriately assesses the proposed project's scientific merit; feasibility of implementing the science; and technical, management, and cost feasibility based on the solicitation's requirements.

NASA has released 13 Earth Venture Class solicitations since 2009 and made its selection for the most recent solicitation—EVI-6—in May 2023.[19] To date, NASA has selected nine EVI projects, which are solicited every 3 years, and three EVM projects, which are solicited every 4 years. According to a 2022 report issued by the National Academies, "Over the past 10 years, NASA has, on average, issued an EVI or EVM solicitation every 17 months…The committee sees important value in maintaining an

[17] In this audit we focused our attention on EVI and EVM projects. We did not examine EVC because there is only one project in that category and it is in early development. Additionally, we did not review EVS because we previously issued a report on that topic in 2017. NASA Office of Inspector General, *Earth Venture Suborbital Investigations* (IG-17-013, March 13, 2017).

[18] The single-step competitive process entails the solicitation, submission, evaluation, and selection of proposals prepared in response to an AO, whereas the two-step competitive process entails Step 1, where multiple proposals are issued awards to conduct Phase A concept studies and Concept Study Reports, and Step 2 for the preparation, submission, evaluation, and continuation decision of the Concept Study Reports.

[19] All solicitations are identified by their category—EVI, EVM, EVC, or EVS—and are given a sequential number that represents how many solicitations have been released to date. The EVI-6 solicitation was released on April 19, 2022, and closed on September 1, 2022.

approximate 18-month cadence for Earth Venture AOs."[20] Table 3 shows the projects selected for each solicitation since 2009.

Table 3: Selected Projects from Earth Venture Class Solicitations

Solicitation	Solicitation Year	Selection Year	Project(s)
EVS-1	2009	2010	• Airborne Microwave Observatory of Subcanopy and Subsurface • Airborne Tropical Tropopause Experiment • Carbon in Arctic Reservoirs Vulnerability Experiment • Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality • Hurricane and Severe Storm Sentinel
EVM-1	2011	2012	• Cyclone Global Navigation Satellite System
EVI-1	2012	2012	• Tropospheric Emissions: Monitoring of Pollution
EVI-2	2013	2014	• Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station • Global Ecosystem Dynamics Investigation
EVS-2	2013	2014	• Atmospheric Carbon and Transport–America • Atmospheric Tomography Mission • North Atlantic Aerosols and Marine Ecosystems Study • Observations of Aerosols above Clouds and their Interactions • Oceans Melting Greenland • Coral Reef Airborne Laboratory
EVI-3	2015	2016	• Multi-Angle Imager for Aerosols • Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats
EVM-2	2015	2016	• Geostationary Carbon Cycle Observatory
EVI-4	2016	2018	• Earth Surface Mineral Dust Source Investigation • Polar Radiant Energy in the Far Infrared Experiment
EVS-3	2017	2018	• Aerosol Cloud Meteorology Interactions over the Western Atlantic Experiment • Dynamics and Chemistry of the Summer Stratosphere • Investigation of Microphysics and Precipitation for Atlantic Coast Threatening Snowstorms • Delta-X • Sub-Mesoscale Ocean Dynamics Experiment
EVI-5	2018	2019	• Geosynchronous Littoral Imaging and Monitoring Radiometer
EVC-1	2018	2020	• Libera
EVM-3	2020	2021	• Investigation of Convective Updrafts
EVI-6	2022	2023	• Polarized Submillimeter Ice-cloud Radiometer

Source: NASA OIG presentation of Agency data.

[20] National Academies, *Lessons Learned in the Implementation of NASA's Earth Venture Class* (2022).

NASA's Review Process Identified Major Weaknesses in Selected Projects

The AO process is governed by 48 C.F.R. 1872, which provided guidance for NASA to develop a Standard PI-led Mission AO Template to use in developing and submitting proposals for solicitations.[21] Section 5 of the template outlines the science, technical, management, and cost requirements and constraints for proposals. While EVI and EVM proposals follow the Standard PI-led Mission AO Template, SOMA documented "major weaknesses" with project management, mission design and operations, and instrument development in the transition package of several selected projects. However, SMD leadership consider these weaknesses correctable by project teams when utilizing available resources and sound project management principles. For example:

- A project's transition briefing noted the instrument delivery schedule from a university partner was inconsistent with the project schedule, mass contingencies and margins for an instrument and flight system were too low, and a Risk Management Plan and Safety and Mission Assurance Plan did not adequately address requirements for the mission.
- A project's transition briefing noted a university partner did not provide a completed schedule for the project and indicated either remarkably low or no time commitments for the Project Manager, Instrument Manager, or Instruments Systems Engineer.
- A project's transition briefing noted a university partner's proposal did not adequately support claims for the stated maturity of the instrument system and the scaling of the optical subsystem and did not provide a plan to advance it to Technology Readiness Level 6—meaning it is at a fully integrated prototype demonstration in a relevant environment—by the Preliminary Design Review.[22]

In addition, NASA is not adequately vetting PIs during the solicitation phase to ensure they have the appropriate experience and time dedicated to adequately manage their projects. For example, the Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats (TROPICS) transition briefing noted the project's organizational structure indicated overlapping responsibilities, conflicting lines of authority, and poorly defined roles. An ESSP Program official also said that Geosynchronous Littoral Imaging and Monitoring Radiometer's (GLIMR) proposal noted the PI had previous contracting experience with NASA; however, not until after the project's selection was it discovered that the previous contracting experience was as a non-NASA subcontractor and not as the prime contractor for a NASA project with a $100 million plus budget such as those under the Earth Venture Class.

[21] 48 C.F.R. Part 1872 (2003).

[22] Technology Readiness Level is a type of measurement system used to assess the maturity level of a particular technology. NASA assigns each technology project a Technology Readiness Level rating of 1 through 9 based on the project's progress, with 1 meaning preliminary research of a basic concept is in the early stage compared to 9 when the technology is integrated into a product and successfully operated in its intended environment. The Preliminary Design Review evaluates the completeness and consistency of the planning, technical, cost, and schedule baselines developed during the Formulation Phase; assesses compliance of the preliminary design with applicable requirements; and determines if the project is sufficiently mature to begin final design and fabrication.

While solicitation, evaluation, and selection of individual projects are conducted by SMD at NASA Headquarters, ESSPPO is responsible for the management, direction, and implementation of the selected opportunities. It is ESSPPO's responsibility to work with the selected project's team to address and correct any major weaknesses identified by SMD during the selection process.

Input from ESSPPO Is Limited During the Solicitation and Evaluation Process

To ensure proposals are independently reviewed and avoid potential conflicts of interest, ESSPPO generally only provides input regarding award management and access to space during the solicitation and evaluation process. In fact, ESSPPO is not notified of the selection of a new project until its public announcement. According to the ESSP Program Manager, while there was no specific incident that caused ESSPPO to be firewalled from the solicitation and evaluation process, the benefit of being involved does not outweigh the risk of perception of conflicts of interest. According to a senior SMD official, this is standard operating procedure and ESSPPO is not involved unless their subject matter expertise is required. While we agree that NASA has valid reasons to limit ESSPPO's involvement in the solicitation and evaluation process, this exclusion can create difficulties in the management of selected projects.

Shortly after public announcement of a project's selection, SOMA provides ESSPPO a transition package that includes the proposal and a briefing with an overview of the planned mission; technical, management, and cost evaluations; findings and recommendations; and a cost risk analysis. However, according to a senior SMD official, the cost evaluations provided in the briefing are not consistently accurate and risk levels are not as conservative as they should be. For example, according to one Program official, they identified early concerns with the Geostationary Carbon Cycle Observatory (GeoCarb) that included facing complexities with instrument development and inadequate time commitments from key project personnel at the University of Oklahoma. According to another Program official, GLIMR immediately experienced major delays with the PI's limited project management experience, lack of expertise and experience of staff, and lack of an access to space option.

Consequently, ESSPPO is in a difficult position when it must manage projects with technical issues whose risks could have potentially been better identified had their office provided its expertise and input earlier during the solicitation and evaluation process. For example, the transition package for GeoCarb noted the available mass margin—the difference between the maximum possible mass (weight) permitted by the launch vehicle and the maximum expected mass under the current design—was inadequate, which was a contributing factor to the substantial increase in costs that lead to the commercial host providing access to space eventually dropping out.[23] ESSPPO's concerns about these issues were apparent from the project's inception and were among the reasons NASA canceled GeoCarb in November 2022 at a cost of approximately $164 million. In fact, a senior SMD official noted there were concerns this project was selected in the first place based on its higher than anticipated risk for the Earth Venture Class portfolio. The Program official noted that had ESSPPO been involved earlier in the process, they could have addressed potential weaknesses in the proposal and prepared in advance to help with project execution.

[23] The difference between mass and weight is that mass is the measurement of how much matter is contained within an object whereas weight is a measurement of how much gravity is pulling down on an object.

Despite efforts from ESSPPO and SMD, they have yet to identify a way to involve the ESSP Program in the selection process and avoid the perception of conflicts of interest. However, a Program official was able to recently sit in on an open session for the EVI-6 solicitation as an observer. In addition, the Program can request information regarding the spectrum of selectees prior to the public announcement of a procurement to better prepare for the potential selected projects and improve program management.

NASA Provides Principal Investigators Inconsistent and Unclear Expectations on Reporting Requirements

NASA AOs identify the solicited mission's risk tolerance class as defined in NASA Procedural Requirements (NPR) 8705.4A.[24] In addition, SMD issued a decision memorandum in 2017 to streamline the process for implementing Class D missions.[25] However, four Earth Venture Class projects solicited as Class D missions—Cyclone Global Navigation Satellite System (CYGNSS), Investigation of Convective Updrafts (INCUS), Polar Radiant Energy in the Far Infrared Experiment (PREFIRE), and TROPICS—believe their projects have been treated as Class C, causing uncertainty among PIs about NASA's expectations for reporting requirements since Class C missions require additional reporting.

In a survey we sent to 33 PIs and Deputy PIs representing 21 projects in ESSP's portfolio, most responses had critical feedback regarding the cost and time associated with submitting proposals.[26] For example, of the 23 responses received, 18 respondents (78 percent) stated the time commitment required to prepare the proposal was high and 13 (57 percent) stated the expense required to complete the proposal was high.[27] One PI noted "the solicitation process is an extraordinary amount of work with little ultimately to show for it unless your mission is selected." Also, four respondents raised issues regarding expectations, management, and oversight of Class D missions. For example, one PI stated that the reporting requirements for a Class D mission are at times unreasonable. The PI further elaborated that their project's Class D mission designation "as opposed to a Class C mission, is sometimes forgotten when it comes to meetings, requirements, and evaluations, all of which have time and budget implications." Another PI stated that it was difficult to manage expectations for a Class D mission with a strict cost cap given the Class D low-cost mission's risk posture did not seem to match the documentation and reporting burden.

In addition, NASA's failure to provide clear expectations on reporting requirements during the solicitation process could result in issues with deliverables post-selection. According to a 2022 National Academies report, "the AO and NASA Procedural Requirements 7120.5F (and documents referenced within) do not present a clear idea about the number and scope of contract data requirements that would be expected during mission implementation. This complicates the budgeting for mission management during the preparation of proposals."[28] For example, two respondents from our survey

[24] NPR 8705.4A, *Risk Classification for NASA Payloads* (April 29, 2021).

[25] NASA SMD, *NASA Science Mission Directorate (SMD) Class-D Tailoring/Streamlining Decision Memorandum* (December 7, 2017).

[26] Polarized Submillimeter Ice-cloud Radiometer (PolSIR) was not contacted for our survey as it was distributed prior to the project's EVI-6 selection in May 2023.

[27] Our survey used a subjective scale of low, medium, or high.

[28] National Academies, *Lessons Learned*.

noted that expectations were not well communicated until long after the project kickoff and there was limited oversight of contract requirements during the solicitation process, with one respondent adding that examples within the solicitation and before kickoff would have been extremely beneficial to help the project team properly prepare.

In speaking to a senior SMD official, the Agency is updating the Standard PI-led Mission AO Template and expects to publish it in late 2023. Changes are based on feedback from proposers, face-to-face debriefings with project teams, input at conferences, and town halls. With the template update, NASA anticipates addressing issues regarding the level of reporting requirements placed on proposals, which can at times make it burdensome, time-consuming, and expensive on proposers.

UNLAUNCHED EARTH VENTURE CLASS PROJECTS FACE COST AND SCHEDULE GROWTH

While the ESSP Program has been successful to date in controlling cost growth and meeting milestones for 18 of its 22 active projects, as of May 2023 more than half of its unlaunched projects face cost and schedule challenges primarily related to subcontractor disruptions and access to space. Failure to address these challenges in a timely manner will result in continued cost growth and schedule delays, which if left unaddressed could ultimately disrupt the Program's efforts to produce relatively low-cost missions.

ESSPPO Has Controlled Costs and Met Project Milestones for Majority of Its Projects

Prior to 2020, no ESSP project had breached its cost cap or experienced any significant cost growth that threatened the success of the ESSP Program's overall goal of delivering relatively inexpensive missions in a 5-year time frame. The ESSP Program Plan establishes the cost, schedule, risk, and technical standards that govern the Program.[29] The Plan contains cost cap and schedule information for the four categories of Earth Venture Class missions and information on program management tools such as the descoping process, which identifies the reduction or deletion of requirements, science objectives, and technical content to recover cost or schedule savings.

CYGNSS, ESSP's first EVM project, is one example of an Earth Venture Class mission considered a major success by Program officials. CYGNSS, selected in 2012 with its PI based at the University of Michigan, was designed to help scientists understand and predict hurricanes. Shortly after the project was selected, it encountered a significant challenge when its primary contractor, NASA's Ames Research Center, tripled its original cost projections for building the mission's equipment. To address this situation, the PI decided to reissue a bid for the project and subsequently reached agreement with the Southwest Research Institute to develop the instrument at a much lower price. CYGNSS launched in December 2016, and after completing its prime mission entered extended operations in March 2019 due to its science benefits, which include providing data on soil moisture and bodies of water such as lakes and rivers.[30] CYGNSS completed its prime mission at a total cost of $155 million, $26 million lower than its Agency Baseline Commitment (ABC) of $181 million.[31]

In addition, two EVI projects currently onboard the International Space Station are examples of missions operating under their estimated total costs. Earth Surface Mineral Dust Source Investigation, which is

[29] NASA ESSPPO-0001, Revision A, *Earth System Science Pathfinder (ESSP) Program Plan* (November 1, 2017).

[30] The prime mission covers the period that a project is planned to operate. Any operations past the prime mission are known as extended operations.

[31] The ABC is an integrated set of program or project requirements, cost, schedule, and technical content and is established at the transition to the Implementation Phase. It is the only official baseline against which a program's or project's life-cycle cost, schedule, and performance are measured.

investigating the role mineral dust plays in the warming or cooling of the atmosphere, cost $110 million, $3 million less than its ABC of $113 million while Global Ecosystem Dynamics Investigation, which analyzes the relationship between atmospheric carbon dioxide and forestation, cost $120 million, $6 million less than its ABC of $126 million.

Unlaunched ESSP Projects Impacted by Cost Growth and Schedule Challenges

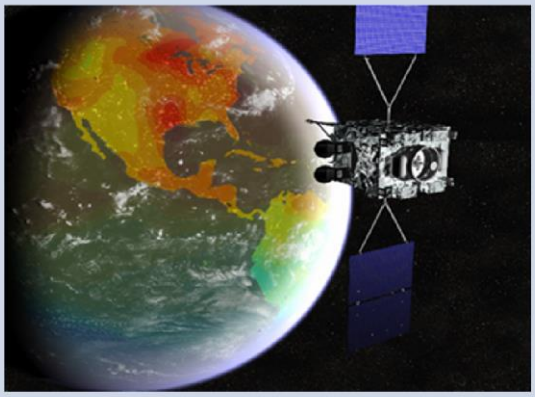
Despite past success within ESSP, as of May 2023, the remaining four of seven unlaunched projects face cost growth and schedule challenges: the now canceled GeoCarb project, GLIMR, Multi-Angle Imager for Aerosols (MAIA), and PREFIRE.[32] These challenges occurred primarily because of subcontractor disruptions, access to space costs, and limited experience of PIs managing projects.

Geostationary Carbon Cycle Observatory (GeoCarb)

GeoCarb, which NASA canceled in November 2022, was designed to monitor carbon gases (such as carbon dioxide), plant health, and vegetation stress throughout the Americas from orbit. This project was one of ESSP's largest and most complex projects with an original life-cycle cost estimate of $171 million. GeoCarb was selected as EVM-2 in 2016 with the PI based out of the University of Oklahoma, which served as the prime contractor, and Lockheed Martin Corporation (Lockheed Martin) as the subcontractor. The project faced significant cost and schedule growth due to poor subcontractor performance and access to space issues that led to its eventual cancellation in November 2022. GeoCarb's cost estimate increased to $634 million at the time of its cancellation which is more than three times its original estimate. By the time it was canceled, NASA had invested $170 million in the project.

According to GeoCarb's PI, the project began to experience cost growth and schedule delays almost immediately after its selection. Lockheed Martin underestimated the work required to complete the GeoCarb instrument within the project's $171 million cost cap, and the company was essentially "playing catch up" from the beginning of the project. According to a Lockheed Martin official, the company and the University of Oklahoma were required to redesign the instrument at its Preliminary Design Review in Phase B due to mass and power issues. The instrument was redesigned to be more compact in response to its mass growth during design and development.

Geostationary Carbon Cycle Observatory



Source: NASA.

Between September 2017 and August 2019, the cost of Formulation Phases A and B (development, preliminary design, and technology completion) grew from $24 million to $61 million necessitating the PI to move funds from the Implementation to the Formulation Phase. After the project moved into

[32] GeoCarb was canceled in 2022, and INCUS, Libera, and PolSIR have not launched yet.

Phase C (final design and fabrication), Lockheed Martin experienced numerous issues during instrument development including breaking or damaging equipment, improperly assembling equipment, and not employing personnel with the proper expertise. Additionally, turnover among the company's staff resulted in delays as the GeoCarb PI had to bring new staff up to speed on project operations and expectations and establish a new working relationship with them.

Lockheed Martin did not complete the instrument's design work before its Critical Design Review, which takes place after Key Decision Point (KDP) C, and the PI believed that NASA should not have conducted the review without the completed design work.[33] GeoCarb was not granted permission to proceed to Phase C at its July 2019 KDP-C due to NASA's concerns over the project's continually growing costs. To control the project's cost growth, GeoCarb's PI decided to convert the company's cost-plus contract into a firm-fixed-priced contract.[34] Under a firm-fixed-price contract, Lockheed Martin would be given a set amount of funding that it would not be able to exceed to complete the project, similar to a cost cap. This effort was ultimately unsuccessful because NASA rejected Lockheed Martin's proposed contract that, from its perspective, inappropriately shifted the risk of completing the project onto the University of Oklahoma and NASA.

As a result of these problems, GeoCarb underwent a Continuation Review in December 2019 and SMD and ESSPPO recommended canceling the project after it was determined the PI could not complete it within the cost cap.[35] By this time, SMD had spent $57 million on the project. NASA's Administrator overruled this decision citing GeoCarb's capability to provide innovative measurements of carbon dioxide and methane and directed GeoCarb to proceed to the Implementation Phase. In addition, at the request of the PI, management of the project was transferred from the PI at the University of Oklahoma to Goddard Space Flight Center (Goddard) in an attempt to address project management issues. However, Goddard experienced similar problems with Lockheed Martin developing the instrument after GeoCarb became a directed mission under its purview.[36]

In July 2020 the relationship with the project's launch provider, SES Government Solutions, ended. Contributing factors that lead to the end of the working relationship were changes in SES Government Solutions' business plans and delays in instrument development. While GeoCarb's instrument was not to exceed 150 kilograms in mass, at one point its mass had reached 200 kilograms. Any mass that exceeded 150 kilograms would have led directly to an increase in access to space costs. According to the PI, the issues with mass were related to deficiencies with Lockheed Martin's designs such as not including harnesses and straps in its plans, all of which adds mass. These issues led the PI to request that NASA procure GeoCarb's access to space.

[33] At KDP-C, a project will either be confirmed to proceed to Phase C (final design and fabrication) or will not be confirmed and will need to continue work in Phase B until corrective actions can be taken. A Critical Design Review is used to determine if a project is ready to proceed with its final design and fabrication work before moving into Phase D for assembly and launch.

[34] With a cost-plus contract, a contractor is reimbursed for its costs along with fees, whereas with a firm-fixed-price contract the contractor is paid a fixed amount regardless of how much it costs the contractor to deliver the product or service.

[35] A Continuation Review is used by NASA to determine if it is possible for a project to complete work within its cost cap and schedule. If it is determined that the project cannot be completed within these parameters, the relevant directorates can recommend the project be formally canceled.

[36] Missions or projects are "directed" or assigned by NASA to a specific institution such as a NASA Center to develop the project and are typically more expensive. In comparison, other missions such as the Earth Venture Class are "competed" or selected as part of a competition such as the AO process and usually include a cost cap.

Following the end of the relationship with SES Government Solutions, GeoCarb could no longer pursue its initial hosting plan and needed an alternative access to space.[37] Ideally, projects leverage hosting or ride sharing opportunities rather than seeking a dedicated access to space option because hosting or ride sharing dramatically reduces cost and risk for space flight projects by sharing both cost and risk between primary and secondary payloads. However, GeoCarb's need for a dedicated access to space solution would lead to significant cost increases. Launch services were estimated to cost $50 million at the time of its 2019 Continuation Review. After the relationship with the company ended in July 2020, NASA released a solicitation for a dedicated access to space option for GeoCarb in April 2022; however, continued delays left the project unable to meet the requirements established in the solicitation. In fact, NASA projected a less than 1 percent probability that GeoCarb could be delivered in accordance with the terms of the April 2022 solicitation. By the time of its cancellation, GeoCarb's dedicated access to space cost was estimated to be $350 million.

From the Continuation Review in December 2019 until GeoCarb's cancellation in 2022, SMD spent an additional $107 million. See Table 4 for a breakdown of the additional costs.

Table 4: GeoCarb Project Cost Difference between First Proposed Cancellation in 2019 and Cancellation in 2022

Project Entities	First Cancellation Attempt (KDP-C Continuation Review) December 2019	Canceled November 2022	Cost Difference
University of Oklahoma Contract	**$55.58 million**	**$151.09 million**	**$95.51 million**
NASA Entities	**$1.05 million**	**$12.74 million**	**$11.69 million**
Jet Propulsion Laboratory, Ames Research Center, Goddard Space Flight Center Science Support	$1.05 million	$1.57 million	$0.52 million
Goddard Space Flight Center Project Office	$0	$8.81 million	$8.81 million
Access to Space Project Office	$0	$2.36 million	$2.36 million
Total	**$56.63 million**	**$163.83 million**	**$107.2 million**

Source: NASA OIG presentation of Agency data.

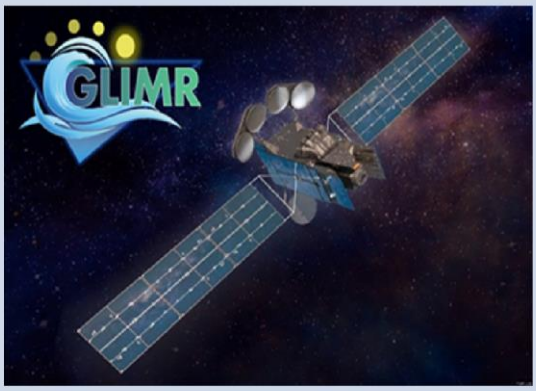
Geosynchronous Littoral Imaging and Monitoring Radiometer (GLIMR)

GLIMR will provide an analysis of coastal zones such as the Gulf of Mexico to observe and monitor ocean biology, chemistry, and ecology to help protect ecosystem sustainability among other activities. The project has a cost cap of $110 million and has yet to set a launch date. GLIMR has experienced cost growth and schedule challenges due, in part, to performance issues with its subcontractor Raytheon Technologies Corporation (Raytheon). Currently, the project is using its reserves to manage these challenges and in December 2022 shifted $6 million from Phase C to Phases A and B. The project has expended $51 million of its $110 million cost cap as of May 2023. Additionally, GLIMR incorporated a

[37] A hosted payload takes advantage of available capacity on commercial satellites and "hitchhikes" on spacecraft already scheduled for launch.

schedule margin of 40 days; however, not only did GLIMR exceed this 40-day buffer, but they also faced an additional 31-day delay due to supply chain issues.[38] According to ESD's Director, GLIMR is at risk of experiencing many of the same issues related to instrument development as GeoCarb had with Lockheed Martin. Another ESD official stated that the PI for GLIMR is having some challenges managing Raytheon, and as a result, NASA has very low confidence that the GLIMR project can be completed within the $110 million cost cap. GLIMR passed KDP-C in March 2023 and the SMD Associate Administrator approved the project to proceed into the Implementation Phase despite dissenting opinions against approval from SMD's Program Management Council and ESSPPO due to GLIMR's cost estimate, the status of the project's cost reserves, schedule delays, eroding schedule margin, technical concerns, and Raytheon's performance on the project.[39] GLIMR currently does not have an access to space option, and NASA will not purchase a ride for the project until after the instrument is sufficiently developed to ensure the project can be completed within an acceptable risk. GLIMR will not have a full life-cycle cost estimate until its access to space option has been identified.

Geosynchronous Littoral Imaging and Monitoring Radiometer



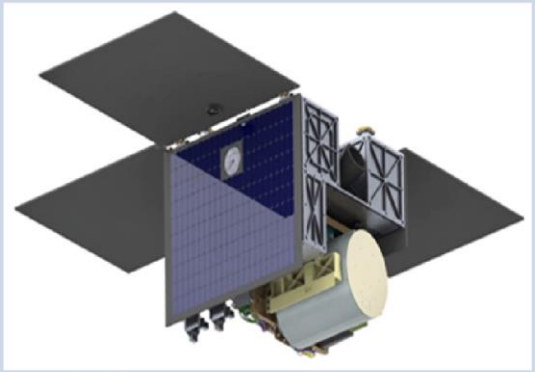
Source: NASA.

In addition, the University of New Hampshire experienced staffing issues such as a lack of expertise by personnel in critical disciplines for the project and initially a Project Manager with experience managing large corporate projects. ESSPPO raised concerns over the university's staffing issues and lack of experience, along with Raytheon's cost estimate for the instrument, all of which led to an 18-month delay at the onset of the project.

Multi-Angle Imager for Aerosols (MAIA)

MAIA will study the impacts of various types of airborne particulate matter on human health. Initially, MAIA's life-cycle cost estimate was $188 million with a planned launch in May 2022. While the cost capped instrument remained within budget, access to space challenges led to significant cost growth and launch delays. MAIA's launch was delayed when NASA and the original launch provider mutually ended the hosting contract due to overall technical and programmatic challenges. Specifically, in August 2018 NASA contracted with General Atomics to provide access to space. General Atomics had recently acquired Surrey Satellite Technology

Multi-Angle Imager for Aerosols



Source: NASA.

[38] Schedule margin is a buffer built into the schedule estimate to provide flexibility to address issues caused by risks and uncertainties.

[39] The Directorate Program Management Council is made up of officials from the directorates that hold Decision Authority over a given project and determine whether or not a project is ready to proceed from one phase to the next.

and intended to use systems previously developed by them. After the acquisition, General Atomics began to experience turnover issues and many of the personnel that originally worked on MAIA's launch left the company. The high staff turnover resulted in continuity issues and delays that caused General Atomics to fail its Hosting Services Critical Design Review. Following the review, NASA decided to end the agreement with the company in October 2021 and find a new access to space option. NASA spent approximately $11 million on the General Atomics access to space contract at the time the agreement was ended.

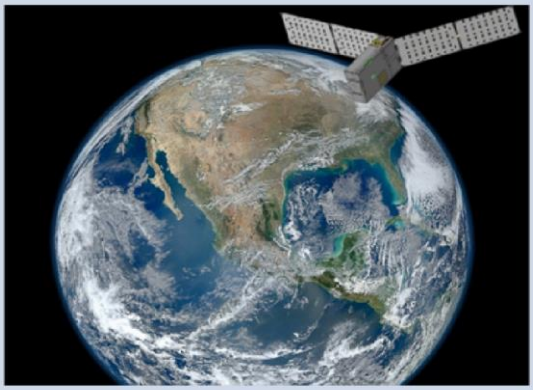
NASA was unable to find an access to space provider at a price that kept costs within the project's original budget. As a result, NASA added $86 million to MAIA's budget for potential increases in access to space costs, which increased MAIA life-cycle cost estimates from $188 million to $274 million. Subsequently, NASA reached an agreement in January 2023 with the Italian Space Agency to launch the instrument in November 2025. As of May 2023, MAIA's life-cycle cost estimate is $226.4 million, launching 3 years later than planned and costing $38.4 million more than the project's initial life-cycle cost estimate.

Polar Radiant Energy in the Far Infrared Experiment (PREFIRE)

PREFIRE will fly a pair of small CubeSat satellites to study the radiant energy emitted by Earth for clues about Arctic warming, sea ice loss, and ice sheet melting. The project, which began in 2018 and is led by a PI from the University of Wisconsin-Madison, is completing testing and will soon enter storage before a planned August 2024 launch. PREFIRE has an ABC of approximately $60 million. PREFIRE has experienced delays with the delivery of its optics by its subcontractor II-VI Incorporated. These supply chain issues hindered II-VI Incorporated's ability to deliver its components in a timely manner and caused the project to tap into its funding reserves to complete an optical component of PREFIRE's instrument. Consequently, project officials had to explore ways to descope—or reduce the scope of work. The PI received approval at the Continuation Review to descope 2 months from its mission operations phase, while maintaining the baseline science, to free up funding for instrument development.

PREFIRE underwent a Continuation Review in December 2022 after it became clear the project's cost reserves for the Implementation Phase were depleting quickly. However, during the review the project was able to find enough reserve funding to continue the mission by eliminating workforce hours that were deemed expendable. According to the PI, the project has not needed to tap into those reserves and believes it is able to add the descoped 2 months back to the planned operations phase. Additionally, one SMD official cited communication issues between the PI and Jet Propulsion Laboratory, the NASA Center partnering with the project, over management of the project and that these issues were not corrected until the Continuation Review.[40]

Polar Radiant Energy in the Far Infrared Experiment



Source: NASA.

[40] The Jet Propulsion Laboratory is s a federally funded research and development center managed for NASA by the California Institute of Technology.

Principal Investigators Lack Project Management Experience

The PIs for GeoCarb and GLIMR, both based out of universities, did not have the previous experience needed to effectively manage large subcontractors like Lockheed Martin and Raytheon, respectively. University-based PIs have also struggled managing ESSP projects due to their unfamiliarity with NASA procedures. For example, PREFIRE's PI stated they were not adequately informed of their role in managing its partner, the Jet Propulsion Laboratory, until its 2022 Continuation Review. Although NASA provides guidance to proposers, including an informational briefing and resources on Agency requirements and project management, PIs typically do not find out their proposals are selected for a period of 9 to 12 months after it has been submitted which could impact their understanding of requirements necessary to effectively manage an Earth Venture Class project. Additionally, while PIs receive further guidance after their proposals are selected, they are not provided any formal training on managing a contractor or project management principles.

According to ESSP's Program Manager, it would not be practical for NASA to provide formal contract and project management training for all PIs after their selection. While ESSPPO provides guidance on NASA's overall program and project management processes and requirements during the Formulation and Implementation Phases, we believe the guidance does not adequately inform PIs to ensure mission success. In addition, a PI's expertise is generally focused on the scientific aspects of a mission. Since it is ultimately the PI's responsibility to assemble a project management team with the requisite knowledge, capability, and capacity to manage the project, it is important that NASA help ensure they have contract and project management training or experience that gives them a solid knowledge base to make prudent decisions, especially when managing large subcontractors.

NASA Missing Opportunities to Optimize Societal Applications in ESSP Projects

While the ESSP Program is making progress incorporating societal applications in its Earth Venture Class projects, these applications remain secondary to science data acquisition, inadequately supported, and under-realized. Specifically, such applications are not a priority in developing or evaluating proposals nor are the development of societal applications a primary focus of ESSPPO oversight. Both Congress and the National Academies have called on NASA to ensure its missions pursue and secure practical benefits, particularly within its Earth science missions and programs. However, NASA has not provided PIs nor SMD personnel with clear guidance regarding the value and expectations for applications. Consequently, their full incorporation into Earth Venture Class projects is limited due to delayed incorporation, inadequate budgets, and an incomplete understanding by individuals involved in ESSP projects.

Importance of Societal Applications in ESSP Projects

An application of science is any use of scientific knowledge for a specific purpose with practical and societal benefits. For example, remote sensing observations of soil moisture and vegetation from CYGNSS are being used to help determine locust breeding grounds in East Africa. This information helps decision-makers predict and prevent locust outbreaks and ultimately prevent or mitigate potential famines. In the NASA Authorization Act of 2022, Congress specifically identifies practical benefits for society as a critical measure of success for Earth science missions and programs.[41] Through the Decadal Surveys, the National Academies provide independent advice to inform policy. The 2007 Decadal Survey recommended the development of Earth Venture Class missions, specifically with a focus on developing new scientific research "or on demonstrating key application-oriented measurements." The 2017 Decadal Survey robustly outlined the importance of applications, specifically recommending NASA reduce barriers to applied uses of remote-sensing research and seek ways to accelerate the transition of scientific research into societal benefits. Similarly, NASA recognizes the value of societal applications. Both NASA's 2022 strategic plan and SMD's 2020-2024 science plan emphasize the value practical applications provide to solve problems and meet challenges, such as the capability to better predict weather hazards in a changing climate.[42] In June 2016, ESD issued a directive that established guidelines for implementing a Project Applications

According to the ESD Director, "Scientific research is not enough. When data can be useful to the taxpayer, we have an obligation to push information out there through applications."

[41] National Aeronautics and Space Administration Authorization Act of 2022, Pub. L. No. 117-167, Title VII (2022).

[42] NASA, *NASA Strategic Plan 2022* (March 28, 2022) and NASA SMD, *Science 2020-2024: A Vision for Scientific Excellence* (May 27, 2020).

Program for NASA-directed projects.[43] The primary goal is to maximize the benefit of ESD's investment by enhancing applications value and overall societal benefits for each project. According to the ESD Director, "Scientific research is not enough. When data can be useful to the taxpayer, we have an obligation to push information out there through applications."

Despite this widespread support, prioritizing and incorporating societal applications in Earth Venture Class projects remains a challenge, in part due to the long-standing and widespread approach of "science first and applications second." Historically, the traditional paradigm of science and applications was to pursue high-quality science first and assume applications would follow, often with less forethought. The 2017 Decadal Survey outlined this widely recognized and slow-to-evolve issue, noting the gap between science and applications is called the "valley of death." Incorporating applications early and intentionally in project development can shrink this gap, accelerate the transition of scientific research into societal benefits, and strengthen both science and applications.

Progress Made Incorporating Societal Applications into Earth Venture Class Projects

Over the past 8 years, Earth Venture Class projects are increasingly incorporating more applications and at earlier stages in project development. While initially not a part of the AO process, applications are currently included in the AO and considered as a factor in project selection. Several projects work closely with Program Applications Leads (PAL) and implement Early Adopters Programs, leading to the successful development of applications.[44] As of April 2023, eight Earth Venture Class projects work with PALs and four have Early Adopters Programs. For example, Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) includes a Program and Project Applications Lead, hosted an Early Adopters Program, and developed several applications after launch such as capturing surface temperature data to create heatmaps.[45] This application was used by a pilot project in Los Angeles to demonstrate the successful effect of cool pavement coatings applied to roads (see Figure 4).[46] The results from ECOSTRESS heatmaps were used to secure an additional $6 million in funding for cool pavement coatings and shade trees in the city's underserved communities.

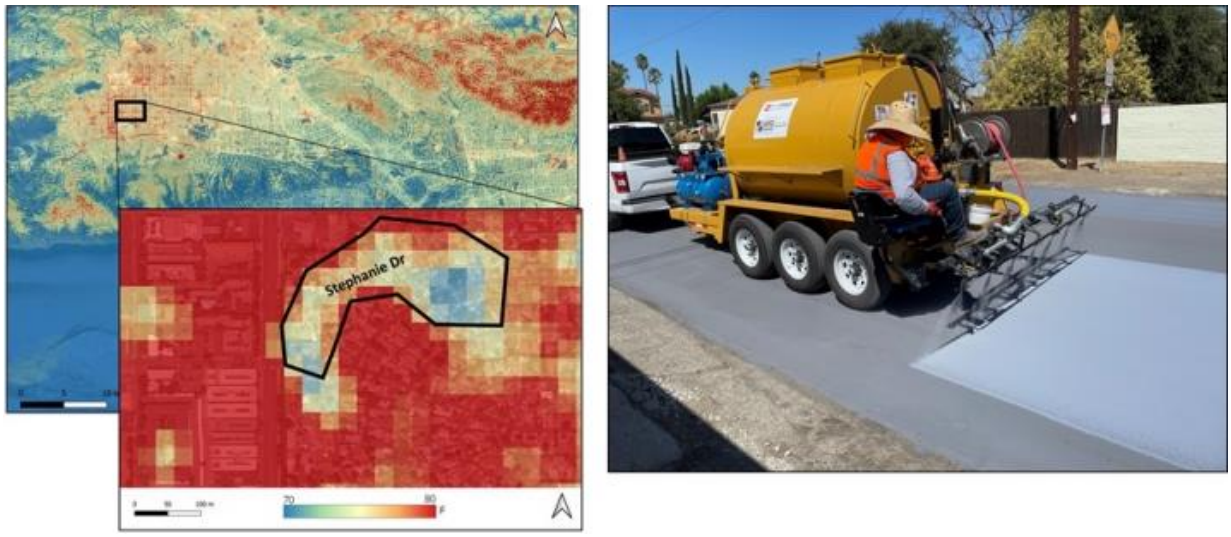
[43] NASA SMD, *Directive on Project Applications Program* (June 29, 2016). The Project Applications Program intends to maximize ESD's investment by developing applications as part of the overall mission concept; demonstrating the project's benefit to society and contribution to achieving societal outcomes; identifying specific product applications and community members who may benefit from applications to better understand the impacts and benefit from using project products; increasing the usefulness of data products; and fostering a community of members who are familiar with NASA products, may potentially benefit from applications, and can work with the project throughout its life cycle.

[44] PALs are NASA officials responsible for supporting the development of applications within projects. Early Adopters Programs seek to accelerate the ingestion and use of NASA data by decision-makers. This involves recruiting potential users and providing them with proxy data products before a launch, training them to use these products, and fostering interactions between the early adopters and project members to enhance algorithms and data products for wider utility.

[45] While a PAL is a NASA official, a Project Applications Lead is a member of the project team responsible for supporting the development of an application within the specific project.

[46] Cool pavements are road surfaces that use various methods to reduce surface temperature heat, especially in urban heat islands. For example, existing dark pavements can be made "cool" with the addition—or coating—of surface treatments that reflect more sunlight or the addition of shading from vegetation or man-made structures.

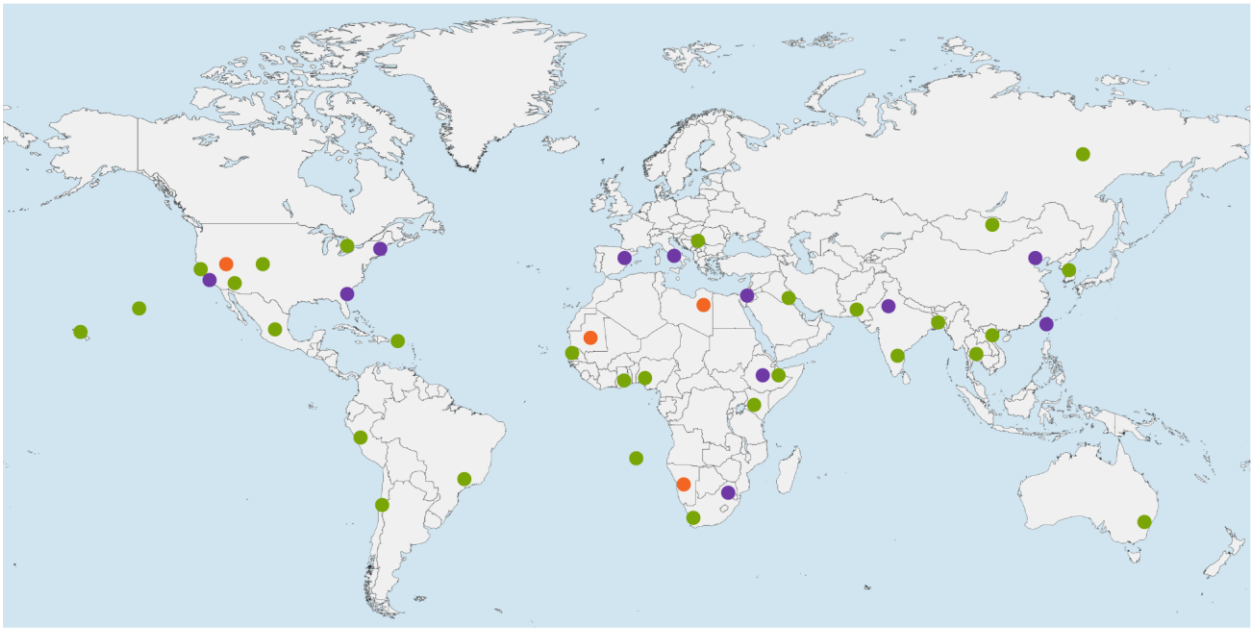
Figure 4: ECOSTRESS Land Surface Temperature Heatmap of Los Angeles (Left) and Worker Applying Cool Pavement Coating in Los Angeles (Right)



Source: NASA.

Most notably, in 2016 NASA selected for the first time an Earth Venture Class project with an applications emphasis. MAIA, the NASA 2016 selection, deliberately incorporated an application as an essential element of the proposal. In addition, MAIA is the first time NASA has partnered with epidemiologists and health organizations on a satellite mission to study human health and improve lives globally. Figure 5 shows MAIA's Primary Target Areas; each is a large metropolitan area where MAIA epidemiologists will study the impacts of various types of airborne particulate matter on human health.

Figure 5: MAIA's Target Areas to Study Impacts of Airborne Particulate on Human Health



Primary Target Areas			
Los Angeles (USA)	Barcelona (Spain)	Tel Aviv (Israel)	Beijing (China)
Atlanta (USA)	Rome (Italy)	Addis Ababa (Ethiopia)	Taipei (Taiwan)
Boston (USA)	Johannesburg (South Africa)	Delhi (India)	

Secondary Target Areas			
Hilo (USA)	Santiago (Chile)	Cape Town (South Africa)	Dhaka (Bangladesh)
Ocean St Cu (Pacific Ocean)	San Juan (Puerto Rico)	Belgrade (Serbia)	Bangkok (Thailand)
San Francisco (USA)	São Paulo (Brazil)	Nairobi (Kenya)	Hanoi (Vietnam)
Phoenix (USA)	Dakar (Senegal)	Harar (Ethiopia)	Ulaanbaatar (Mongolia)
Denver (USA)	Accra (Ghana)	Kuwait City (Kuwait)	Yakutsk (Russia)
Mexico City (Mexico)	Ocean St Cu (Atlantic Ocean)	Karachi (Pakistan)	Seoul (South Korea)
Toronto (Canada)	Lagos (Nigeria)	Chennai (India)	Sydney (Australia)
Lima (Peru)			

Calibration/Validation Target Areas			
Railroad Valley (USA)	Mauritania 1 (Mauritania)	Gobabeb (Namibia)	Libya 4 (Libya)

Source: NASA OIG presentation of Agency information.

MAIA is a promising example of early collaboration focused on both science and applications. In comparison, PREFIRE, which was selected in 2018 and will collect data on projected rates of Arctic warming, sea ice loss, ice sheet melt, and sea level rise, currently involves no practical applications and does not have a formal Early Adopters Program. While societal applications are increasingly incorporated into Earth Venture Class projects, they remain limited due to delayed incorporation in projects' development, inadequate budgets, and an incomplete understanding by individuals involved in ESSP projects.

NASA Does Not Prioritize Societal Applications in the Solicitation, Development, and Management of ESSP Projects

Solicitation. Applications are loosely required, poorly understood by many proposers, and nominally considered by the review panel during the AO solicitation process. Historically, ESSP proposals did not require the inclusion of potential applications. While this became a requirement in 2015, proposers may opt out of the application requirement by providing justification of why there is no viable application dimension to the proposal. In a survey sent to 33 PIs and Deputy PIs, 5 of 21 responses (24 percent) reported including no potential applications in their proposals, with 9 (42 percent) reporting the inclusion of 1 to 2 potential applications.[47] In addition, 18 of 23 responses (78 percent) reported allocating no or a minimal amount of their project budget to applications.

According to one ESD official, confusion regarding the importance of applications stems from a general misinterpretation of applications as well as unclear language in the AO. This official further stated that applications are interpreted by many proposers as applying data to further scientific research rather than applying data "to create real meaningful use such as using data to improve communities." In addition, while the language in AOs regarding the importance of and requirement for applications has improved, it remains unclear. This is evident in the most recent selection of the Investigation of Convective Updrafts (INCUS). The PI and Colorado State University included applications for INCUS in their proposal, but these applications focused primarily on furthering research rather than practical or societal benefits and the proposal did not allocate any budget for development of societal applications. After selection, the PI, Deputy PI, ESSPPO staff, and Applied Sciences Program staff met to discuss these issues and develop a plan to incorporate and support practical applications with INCUS.[48]

Although applications are central to Earth science missions and programs and a priority of NASA, practical applications included in the proposals are framed as secondary and not independently evaluated. For example, in the November 2020 AO for the EVM-3 solicitation, applications were evaluated as part of the science merit element. While applications were included under two of four science merit factors in the evaluation criteria, the language was broad and their weight was unclear. This AO highlighted the importance of applications, noting that selected projects can help achieve NASA's strategic goals "by considering innovative and practical applications." However, applications were framed not as a priority but "as part of the overall mission concept."

Development. Historically, societal applications were not incorporated into projects until after launch. At that time, projects typically used the ROSES process to solicit other investigators to propose applications that built off the science generated by their missions. In the past several years, however, PIs and ESSPPO staff have expressed an increasing awareness and interest in early incorporation of applications. For example, several projects worked closely with PALs and implemented Early Adopters Programs. According to a NASA November 2021 report, 11 flight projects implemented Early Adopters-

[47] Because of skip logic, which routed respondents to follow-up questions only where appropriate, not all respondents were required to answer each question. See Appendix A for details.

[48] NASA's Applied Sciences Program discovers and demonstrates innovative uses and practical benefits of NASA Earth science and data from NASA's Earth-observing environmental satellites. By partnering with government agencies and businesses to apply scientific findings and satellite data in their decision-making activities, the Applied Sciences Program delivers benefits of Earth science to society.

like programs in the last decade.[49] Of the 11 projects, 5 were Earth Venture Class projects. Nevertheless, NASA continues to lack a common approach to incorporating applications.

In our survey and an interview, two PIs described applications as occurring "serendipitously" and being "organic." Multiple PIs expressed surprise by the level of interest in their data when they began engaging early adopters or potential users. For example, GLIMR hosted a meeting on potential data applications anticipating 30 attendees. Instead, the meeting included 350 attendees. One PI noted that some PIs may be reluctant to proactively pursue applications as they do not view applications as "real science." This perception of "real science" is a further manifestation of the long-standing paradigm of science first, applications second. "Curiosity-inspired" science is the traditional pursuit while "use-inspired" science or applications remains secondary. Additionally, ESSPPO implemented an internal proposal to set aside $850,000 to fund small application activities. As a result, three Earth Venture Class projects hosted workshops to solicit and educate community members interested in their data. However, this funding is time-limited, elapsing in 2023, with no indication to pursue similar activities. Without funding, many projects will be unable to pursue applications until launch as they allocated no budget in their proposals and must then wait for launch to leverage the ROSES process. While showing progress, development of applications remains secondary to the pursuit of scientific research.

Management. Similarly, societal applications are not a primary focus of ESSPPO oversight. In our survey of PIs and Deputy PIs, ratings varied significantly when asked about the support ESSPPO provided to incorporate applications into their projects. While 8 of 23 responses (35 percent) rated the support as high, 13 respondents (57 percent) rated the support as none or minimal. Crucially, PIs rated the overall support by ESSPPO highly, but their ratings related to applications reflect a gap in ESSPPO support. ESSPPO focuses primarily on the technical, cost, and schedule elements of projects. According to ESSPPO leadership, applications are not a part of their purview, but rather are outsourced and treated similarly to science. For example, ESSPPO is not required nor does it staff applications experts, similar to how it does not staff science experts, but instead relies on PALs and program scientists respectively to inform the office of any concerns about applications.

ESSPPO relies on several documents to guide the Program, including the ESSP Program Plan and ESSPPO Organizational Plan.[50] The Program Plan provides a detailed overview of the Program; science requirements; and a control plan for technical, cost, and schedule requirements for projects.[51] While this plan covers a variety of topics, it provides minimal information on applications. Program scientist is referenced nine times but there is no mention of PALs. The Program Plan characterizes the Earth Venture Class missions as "designed to advance Earth science research innovatively." Notably, this characterization does not include applications despite the 2007 Decadal Survey identifying applications as a primary focus for these missions. The ESSPPO Organizational Plan outlines the Program's organization and describes the roles and responsibilities for the positions within the office. However, the plan does not identify any roles or responsibilities as it relates to applications support or oversight. ESSPPO leadership stated that future Program Plan updates will include more emphasis on applications and align with future AOs.

[49] NASA, *Assessment of the Early Adopters Programs* (November 4, 2021).

[50] NASA ESSPO-0009, *ESSPPO Organizational Plan* (April 26, 2020).

[51] A control plan is a program or project-level document intended to support an integrated, organized summary of a program's or project's planning and control activities. The plan describes the guidelines and processes used to monitor and control program or project requirements, technical design, schedule, and cost to achieve program or project requirements.

ESD's Applied Sciences Program provides support for the development of applications within Earth Venture Class projects such as by providing PALs, but there is limited buy-in and coordination by ESSPPO. SMD officials observed that PALs tend to be more closely integrated with the project team rather than ESSPPO and are often brought into conversations with the program scientist and PI later in the process. One ESSP Program official noted applications are not a routine part of "conversations," "concerns," or "thought processes" with Mission Managers. Although SMD issued applications directives in 2016 and 2018, the first one does not apply to Earth Venture Class projects while the second one did apply but was withdrawn. According to one ESSPPO official, the second directive was withdrawn due to concerns about creating confusion by having an Earth Venture Class-specific directive along with an ESD one. Neither directive clearly identifies responsible parties. Without explicit formal guidance, roles, and responsibilities, ESSPPO will maintain its narrow focus and accept limited oversight responsibility for applications. As a result, there is limited understanding and engagement with applications as well as minimal formal tracking of project applications. Similarly, while the Applied Sciences Program is trying to support Earth Venture Class projects and applications, their efforts are constrained by a lack of clear guidance and authority.

NASA's Secondary Approach Hinders Development of Critical Societal Applications

With their emphasis on innovation and rapid development, ESSP projects are particularly poised to respond to our changing climate, swiftly provide data, and develop applications to provide actionable information. When GLIMR hosted a meeting on potential data applications, not only did 11 times as many people attend as expected, but 21 percent of attendees were federal, non-profit, foreign, or other decision-makers interested in the data for environmental decision-making, such as determining closures of water bodies due to harmful algal blooms or other hazards. Following the ECOSTRESS launch, NASA solicited additional investigations for applications with the Agency anticipating 6 proposals but receiving over 90. Both examples reflect high levels of community interest that was unanticipated by both PIs and NASA, but they also may suggest high levels of missed opportunities for further applications. Potential applications of Earth Venture Class projects range widely from wildfire prediction to crop yield maximization to oil spill assessment.

While the ESSP Program is making progress, its current approach continues to hinder the development of societal applications in Earth Venture Class projects. This approach does not prioritize the inclusion and evaluation of applications in proposals, results in inadequate funding, and creates unclear expectations and ill-defined responsibilities for everyone involved. Ultimately, this secondary focus on applications will likely result in diminished returns on investment and missed opportunities to provide critical societal benefits.

CONCLUSION

NASA competitively selects research opportunities through its high-risk, high-reward ESSP Program, which provides relatively inexpensive science instruments and missions that can produce timely information to address our changing climate and combat geological hazards and disasters.

Although NASA has provided periodic opportunities to advance Earth science research, improvements can be made to the solicitation, evaluation, and selection process to help the ESSP Program better manage its projects. In addition, while the ESSP Program has been successful in controlling cost growth and meeting milestones for a majority of its projects already launched, four of its seven unlaunched projects face cost and schedule challenges primarily due to subcontractor disruptions, access to space costs, and PIs' limited contractor management experience. Finally, although the Program has made progress supporting the development of societal applications in its Earth Venture Class projects, without specific requirements or a funding methodology they are likely missing opportunities to provide critical support to communities impacted by disaster events since incorporating applications in its projects remain secondary and inadequately supported. For example, while applications became a loose proposal requirement in 2015, many proposers continue to opt out, which is reflected in the quarter of PI respondents who reported including no potential applications in their proposals.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To improve NASA's management of its Earth System Science Pathfinder Program, we recommended NASA's Associate Administrator for Science Mission Directorate:

1. Develop an improved methodology to ensure subject matter expertise from the ESSP Program is better incorporated during the AO process to help mitigate technical, cost, and schedule risks while averting conflicts of interest.
2. Reexamine its selection process to ensure PIs or their teams have sufficient experience, including project management, and the ability to dedicate necessary resources to effectively manage ESSP projects.
3. Reissue and require SMD stakeholders to follow the tenets of the 2017 decision memorandum on Class D missions (Class D Tailoring/Streamlining Decision Memorandum, December 7, 2017).
4. In collaboration with NASA's Launch Services Program, develop a process to engage early and evaluate alternative launch options in the event that ESSP projects encounter access to space issues.
5. Conduct a lessons learned review of the GeoCarb mission to identify what NASA, PI, and contractor practices and activities should be revised and applied to the management of future Earth Venture Class projects.
6. Develop a plan to provide PIs and their teams with contract and project management training post-selection approval to better equip them to manage subcontractors.
7. Develop formal and clear guidance on the roles, responsibilities, and expectations for the inclusion of applications within Earth Venture Class projects.
8. Develop a methodology for funding applications in Earth Venture Class projects.

We provided a draft of this report to NASA management who did not concur with recommendation 1 and concurred or partially concurred with recommendations 2 through 8. In response to recommendation 1, management stated that SMD works to incorporate expertise from individuals outside of ESSPPO, which prevents any appearance of bias or conflict of interest. After further discussions with Agency management, we concluded that their actions are well-informed and meet the intent of the recommendation; therefore, the recommendation is resolved and closed. We also consider management's comments to recommendations 2 through 8 responsive and those recommendations are resolved and will be closed upon completion and verification of the corrective action.

Management's comments are reproduced in Appendix C. Technical comments provided by management and revisions to address them have been incorporated as appropriate.

Major contributors to this report include Ray Tolomeo, Science and Aeronautics Research Audits Director; Adrian Dupree, Assistant Director; Matthew Anderson; Sarah Hughes; and David Lu. Norm Conley and Shari Bergstein provided data analytics assistance. Lauren Suls provided editorial and graphic support.

If you have questions about this report or wish to comment on the quality or usefulness of this report, contact Laurence Hawkins, Audit Operations and Quality Assurance Director, at 202-358-1543 or laurence.b.hawkins@nasa.gov.

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Paul K. Martin
Inspector General

APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from July 2022 through July 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

The scope of this audit included assessing NASA's management of the ESSP Program. In this audit we focused our attention on EVI and EVM projects. We did not focus on EVC because there is only one project in that mission category and it is in early development. Additionally, we did not review EVS because we previously issued a report on that matter in 2017. We evaluated whether the ESSP Program is (1) providing frequent periodic opportunities for developing Earth Venture Class projects, (2) effectively controlling mission and project costs and meeting milestones within established NASA risk and technical standards, and (3) collecting science data that advances NASA's Earth system science and climate research.

To determine whether NASA is providing frequent periodic opportunities for developing Earth Venture Class projects, we interviewed SMD, ESD, ESSPPO, and SOMA officials to gain an understanding of the solicitation, evaluation, and selection process. In addition, we reviewed the Standard PI-led Mission AO Template to better understand the guidance used for the solicitation process. We reviewed transition briefings for five projects created by SOMA that included identification of technical, management, and cost risks. We also reviewed a 2022 report issued by the National Academies that provided an overview of lessons learned for NASA's Earth Venture Class as well as their findings and recommendations.

To determine whether the ESSP Program is effectively controlling mission and project costs and meeting milestones, we interviewed SMD, ESD, ESSPPO, and Goddard officials as well as PIs and project subcontractors to gain an understanding of projects that experienced cost and schedule challenges. We analyzed documents from ESSP unlaunched projects which included reviewing KDP documents for GeoCarb, GLIMR, MAIA, and PREFIRE to identify the causes of cost and schedule challenges. Additionally, we analyzed GeoCarb's contract to track cost growth during its life cycle. In the case of PREFIRE, we reviewed its Continuation Review to determine the project's status. We also obtained and examined the agreement between NASA and the Italian Space Agency to determine the estimated cost for MAIA's launch.

To evaluate NASA's efforts to collect science data that addresses NASA's Earth system science and climate research priorities, we interviewed SMD, ESD, Applied Sciences Program, and ESSPPO officials to gain an understanding of data collection and use as well as the solicitation, development, and management of applications. We reviewed and analyzed documents, including the National Academies 2007 and 2017 Decadal Surveys, NASA's 2022 strategic plan, and SMD's 2020-2024 science plan to better understand the importance, expectations, and requirements regarding practical applications within Earth science missions and projects. We reviewed and analyzed two Project Applications Program directives, the ESSP Program Plan, and the ESSPPO Organizational Plan to identify guidance provided to ESSPPO officials for supporting applications within Earth Venture Class projects.

We developed a survey questionnaire to gather individual perspectives on specific aspects of the ESSP Program, as opposed to making statistical projections. We conducted a 36-question survey of current PIs and Deputy PIs to gather information on their roles and responsibilities, expectations set by NASA,

application development, project challenges, and their experiences throughout including during solicitation and project development. Because of skip logic, which routed respondents to follow-up questions only where appropriate, not all respondents were required to answer each question. We sent the survey to 33 people and received 23 responses. Upon further review, it became apparent that a minority of respondents had worked together to complete a single survey response in an effort to provide more accurate answers. Although we intended for each respondent to answer the survey independently, we accepted the responses as is and counted each completed survey as 1 response for reporting purposes. We had follow-up interviews with 5 PIs for additional information based on their survey responses.

Finally, we reviewed federal and NASA criteria, policies, procedures, and supporting documentation; prior audit reports; external reviews; and other documents related to the ESSP Program. The documents we reviewed included, but were not limited to, the following:

- National Aeronautics and Space Administration Authorization Act, 2022, Pub. L. No. 117-167, Title VII (2022)
- NPR 7120.8A, *NASA Research and Technology Program and Project Management Requirements (Updated w/Change 2)* (September 14, 2018)
- NPR 8705.4A, *Risk Classification for NASA Payloads* (April 29, 2021)
- NPR 7120.5F, *NASA Space Flight Program and Project Management Requirements* w/Change 1 (August 3, 2021)
- NPR 8000.4C*, Agency Risk Management Procedural Requirements* (April 19, 2022)

Assessment of Data Reliability

We used limited computer-processed data that was submitted by NASA officials to evaluate the Agency's management of the ESSP Program. Although we did not independently verify the reliability of this information, we compared it with other available documents to determine data consistency and reasonableness. Generally, we concluded the data was valid and reliable for the purposes of the review.

Review of Internal Controls

We reviewed internal controls associated with NASA's management of the ESSP Program relative to providing opportunities for developing Earth Venture Class projects, effectively controlling mission costs, and meeting project milestones as well as using collected science data to address NASA's Earth system science and climate research priorities. Control weaknesses are identified and discussed in this report. Our recommendations, if implemented, will improve those identified weaknesses.

Prior Coverage

During the last 6 years, the NASA Office of Inspector General has issued four reports of significant relevance to the subject of this report. Unrestricted reports can be accessed at https://oig.nasa.gov/audits/auditReports.html.

NASA's Management of the Stratospheric Observatory for Infrared Astronomy Program (IG-20-22, September 14, 2020)

Management of NASA's Europa Mission (IG-19-019, May 29, 2019)

Earth Venture Suborbital Investigations (IG-17-013, March 13, 2017)

NASA's Earth Science Mission Portfolio (IG-17-003, November 2, 2016)

APPENDIX B: EARTH SYSTEM SCIENCE PATHFINDER PROJECTS

This appendix provides a brief overview of the ESSP Program's 22 active projects including phase status, launch date or planned launch date, project costs as of May 2023, and a description of the project.

Aerosol Cloud Meteorology Interactions over the Western Atlantic Experiment (ACTIVATE)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	February 14, 2020[a]	$23.2 million

The Aerosol Cloud Meteorology Interactions over the Western Atlantic Experiment studies how aerosol particles change clouds and vice versa in ways that affect Earth's climate system. The data obtained will be used to quantify relationships between aerosol number concentration, cloud condensation nuclei number concentration, and cloud drop number concentration to reduce uncertainty in model parameterizations of cloud droplet activation. The results obtained will improve process-level understanding and model representation of factors that govern cloud physical properties and how they couple with cloud effects on aerosol.

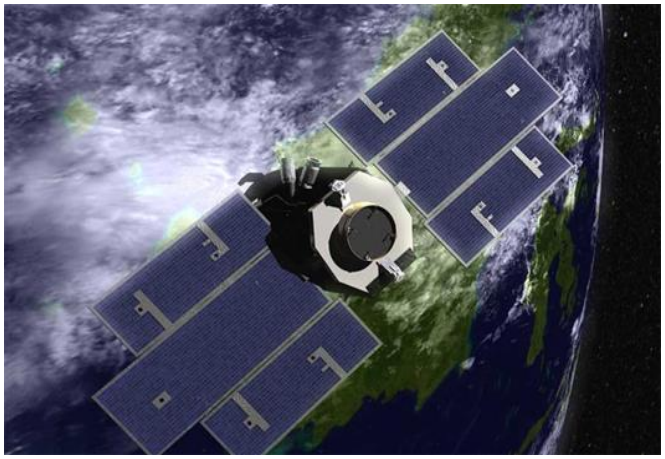
[a] There were six deployments over a nearly 2.5-year period—first deployment took flight on February 14, 2020, and the last occurred on May 3, 2022.

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	April 28, 2006	$123.8 million

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation spacecraft studies the role that clouds and aerosols play in regulating Earth's weather, climate, and air quality. It combines an active lidar instrument with passive infrared and visible imagers to probe the vertical structure and properties of thin clouds and aerosols over the globe.

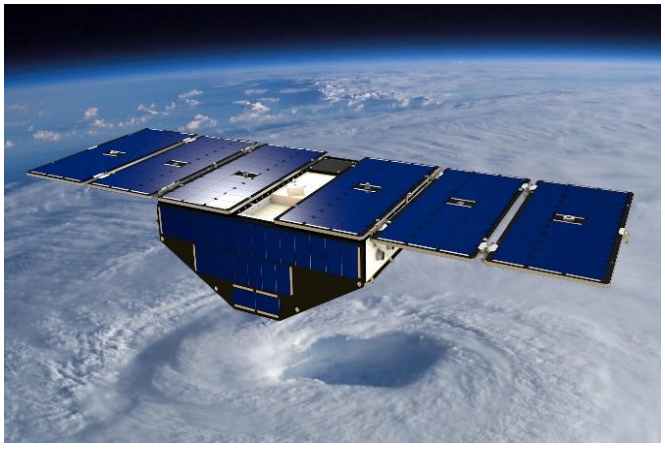
CloudSat		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	April 28,2006	$145.8 million

CloudSat uses advanced radar to examine the inner structure of clouds, helping researchers better understand how severe tropical cyclones and climate changes related to clouds occur.



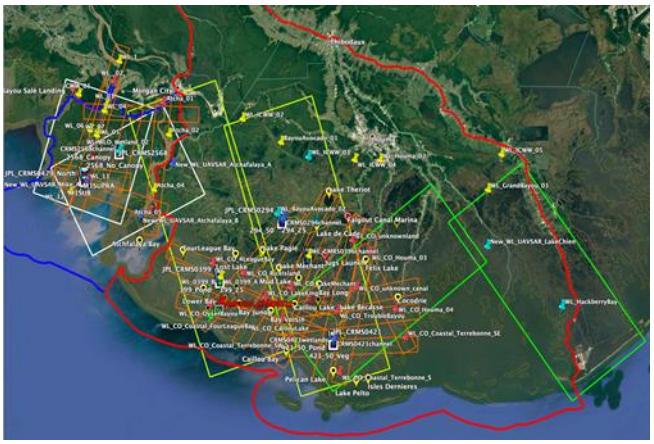
Cyclone Global Navigation Satellite System (CYGNSS)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	December 15, 2016	$182.7 million

The Cyclone Global Navigation Satellite System mission uses eight micro-satellites to measure wind speeds over Earth's oceans, increasing the ability of scientists to understand and predict hurricanes. Each satellite takes information based on the signals from four GPS satellites.



Delta-X		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	March 24, 2021[a]	$12.3 million

The Delta-X investigation quantifies patterns of soil accretion that control land loss and gain and predict the resilience of deltaic floodplains under projected relative sea level rise, aiding in the understanding of and mitigating the impact of sea level rise on coastal deltas.



[a] There were two deployments over a 5-month period—first deployment took flight on March 24, 2021, and the second occurred on August 17, 2021.

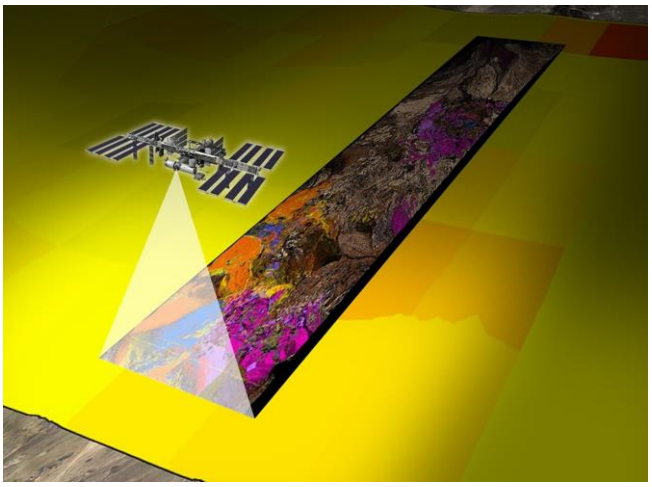
Dynamics and Chemistry of the Summer Stratosphere (DCOTSS)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	July 12, 2021[a]	$22.4 million

The Dynamics and Chemistry of the Summer Stratosphere research investigation studies the coupling of the tropopause-penetrating convection with the large-scale monsoonal motion in this region, as well as the impact of convection on the chemical composition of the lower stratosphere.

[a] There were two deployments over a nearly 1-year period—first deployment took flight on July 12, 2021, and the second occurred on May 26, 2022.

Earth Surface Mineral Dust Source Investigation (EMIT)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	July 14, 2022	$110.9 million

The Earth Surface Mineral Dust Source Investigation on the International Space Station maps the mineral composition of arid dust source regions via imaging spectroscopy in the visible and short-wave infrared range. The maps of the source regions are used to model the role of mineral dust in the warming or cooling of the atmosphere.

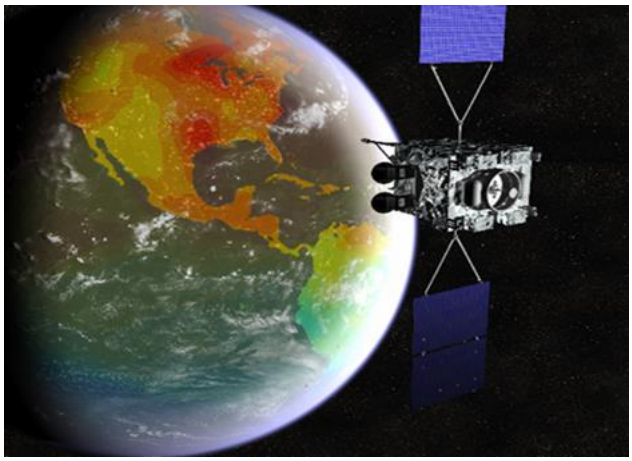


Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	June 29, 2018	$66.1 million

The Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station is a thermal instrument on the International Space Station that measures the temperature of plants to understand plant stress. Its primary mission is to identify critical thresholds of water use and water stress in plants and detect the timing, location, and predictive factors leading to plant water uptake decline and/or cessation.

Geostationary Carbon Cycle Observatory (GeoCarb)		
Status	**Planned Launch Date**	**Project Costs as of May 2023**
Canceled	Canceled	$170.4 million

The Geostationary Carbon Cycle Observatory planned to monitor plant health and vegetation stress throughout the Americas, and to probe, in unprecedented detail, the natural sources, sinks, and exchange processes that control carbon dioxide, carbon monoxide, and methane in the atmosphere. It would have collected 5 million daily observations of the concentrations of carbon dioxide, methane, carbon monoxide, and solar-induced fluorescence at a spatial resolution of about 3 to 6 miles.



Geosynchronous Littoral Imaging and Monitoring Radiometer (GLIMR)		
Status	**Planned Launch Date**	**Project Costs as of May 2023**
Formulation	To Be Determined	$50.9 million

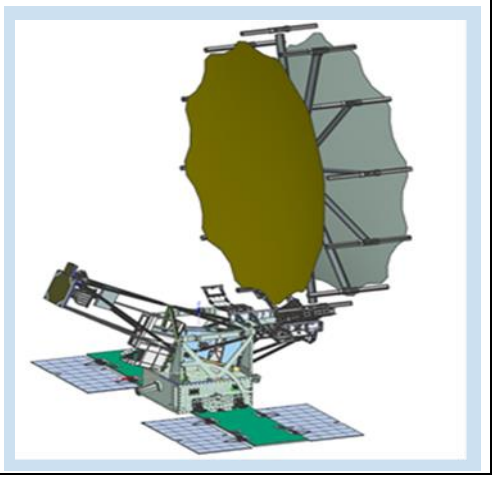
The Geosynchronous Littoral Imaging and Monitoring Radiometer instrument fills a significant gap by providing rapid analysis of dynamic coastal zones throughout the Gulf of Mexico, southeastern U.S. coastline, and Amazon River to observe and monitor ocean biology, chemistry, and ecology to help protect ecosystem sustainability, improve resource management, and enhance economic activity. This includes identifying and tracking harmful algal blooms and oil spills, while also observing, quantifying, and understanding processes associated with rapid changes in phytoplankton growth.

Global Ecosystem Dynamics Investigation (GEDI)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	December 5, 2018	$127.7 million

The Global Ecosystem Dynamics Investigation provides answers to how deforestation has contributed to atmospheric carbon dioxide concentrations, how much carbon forests will absorb in the future, and how habitat degradation will affect global biodiversity. It observes nearly all tropical and temperate forests using a self-contained laser altimeter on the International Space Station.

Investigation of Convective Updrafts (INCUS)		
Status	**Planned Launch Date**	**Project Costs as of May 2023**
Formulation	August 2026	$16.3 million

The Investigation of Convective Updrafts will study the behavior of tropical storms and thunderstorms, including their impacts on weather and climate models. The mission will be a collection of three SmallSats flying in tight coordination. It aims to directly address why convective storms, heavy precipitation, and clouds occur exactly when and where they form.



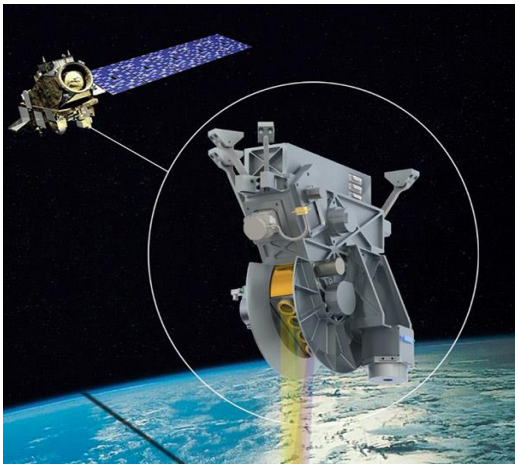
Investigation of Microphysics and Precipitation for Atlantic Coast Threatening Snowstorms (IMPACTS)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	January 12, 2020[a]	$21.3 million

The Investigation of Microphysics and Precipitation for Atlantic Cost Threating Snowstorms provides observations critical to understanding the mechanisms of snowband formation, organization, and evolution. It also examines how the microphysical characteristics and likely growth mechanisms of snow particles vary across snowbands. Additionally, it improves snowfall remote sensing interpretation and modeling to significantly advance predictive capabilities.

[a] There were three deployments over a 2-year period—first deployment took flight on January 12, 2020, and the last occurred on January 6, 2022.

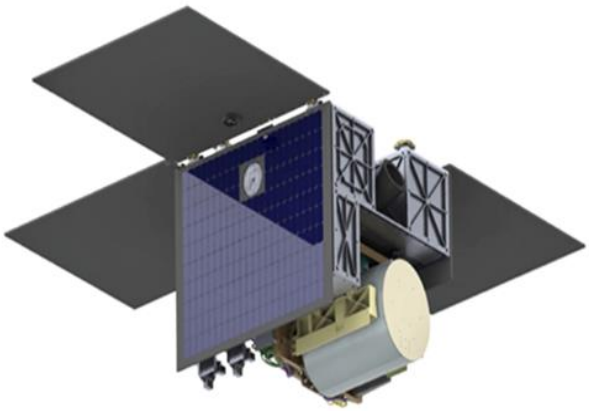
Libera		
Status	**Planned Launch Date**	**Project Costs as of May 2023**
Implementation	January 2027	$44 million

The Libera instrument is a new sensor that will fly on the Joint Polar Satellite System-4 mission and observe the balance between solar radiation entering Earth's atmosphere and the amount absorbed, reflected, and emitted. This radiation balance is a key factor in determining our climate—if Earth absorbs more heat than it emits, it warms up; if it emits more than it absorbs, it cools down.



Multi-Angle Imager for Aerosols (MAIA)		
Status	**Planned Launch Date**	**Project Costs as of May 2023**
Implementation	November 2025	$124.8 million

The Multi-Angle Imager for Aerosols will make radiometric and polarimetric measurements needed to characterize the sizes, compositions, and quantities of particulate matter in air pollution. Researchers will combine MAIA measurements with population health records to better understand the connections between aerosol pollutants and health problems such as adverse birth outcomes, cardiovascular and respiratory diseases, and premature deaths.



Orbiting Carbon Observatory-2 (OCO-2)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	July 2, 2014	$471.6 million

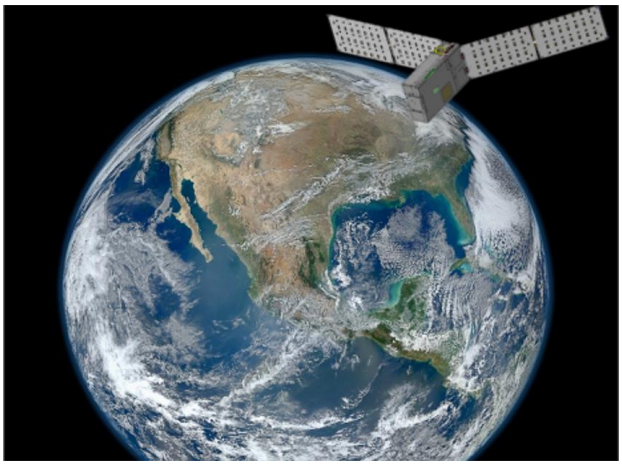
The Orbiting Carbon Observatory-2 is an exploratory science mission that collects space-based global measurements of atmospheric carbon dioxide with the precision, resolution, and coverage needed to characterize sources and sinks on regional scales. It also quantifies carbon dioxide variability over the seasonal cycles year after year.

Orbiting Carbon Observatory-3 (OCO-3)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	May 4, 2019	$105.8 million

Orbiting Carbon Observatory-3 is mounted on the International Space Station. It investigates important questions about the distribution of carbon dioxide on Earth as it relates to growing urban populations and changing patterns of fossil fuel combustion.

Polar Radiant Energy in the Far Infrared Experiment (PREFIRE)		
Status	**Planned Launch Date**	**Project Costs as of May 2023**
Implementation	August 2024	$35.6 million

The Polar Radiant Energy in the Far Infrared Experiment will fly a pair of small CubeSat satellites to probe a little-studied portion of the radiant energy emitted by Earth for clues about Arctic warming, sea ice loss, and ice sheet melting. It will fly miniaturized thermal infrared spectrometers on two CubeSat satellites, each about the size of a loaf of bread.



Polarized Submillimeter Ice-cloud Radiometer (PolSIR)		
Status	**Planned Launch Date**	**Project Costs as of May 2023**
Formulation	2027	$0

The Polarized Submillimeter Ice-cloud Radiometer will study ice clouds that form high above tropical and subtropical regions of the Earth. Sensors will be mounted on two small satellites and launched into low Earth orbit where they will collect data on how ice clouds change over the course of a day.

Sub-Mesoscale Ocean Dynamics Experiment (S-MODE)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	May 3, 2021[a]	$17.7 million

The Sub-Mesoscale Ocean Dynamics Experiment tests the hypothesis that submesoscale ocean dynamics make important contributions to the vertical exchange of climate and biological variables in the upper ocean. This will require the coordinated application of newly developed in situ and remote sensing techniques and provide an unprecedented view of the physics of submesoscale eddies and fronts and their effects on vertical transport in the upper ocean.

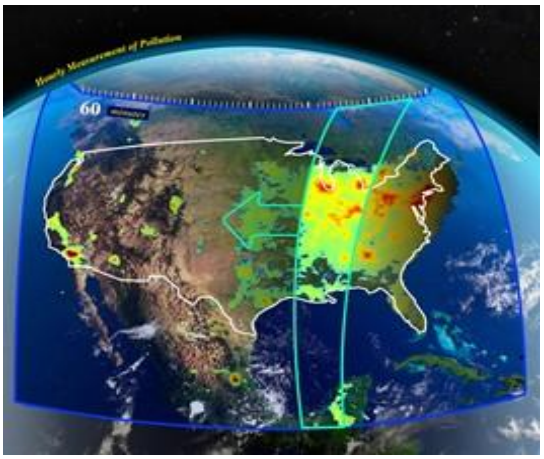
[a] There were four deployments over a nearly 2-year period—first deployment took flight on May 3, 2021, and the most recent occurred on March 3, 2023. This last deployment remains ongoing.

Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats (TROPICS)		
Status	**Launch Date**	**Project Costs as of May 2023**
Implementation	May 8 and 26, 2023	$51 million

The Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats mission is a constellation of four state-of-the-art science observing platforms that will measure temperature and humidity soundings and precipitation with spatial resolution comparable to current operational passive microwave sounders but with greatly improved resolution.

Tropospheric Emissions: Monitoring of Pollution (TEMPO)		
Status	**Launch Date**	**Project Costs as of May 2023**
Operations	April 7, 2023	$187.2 million

The Tropospheric Emissions: Monitoring of Pollution instrument is a UV-visible spectrometer and the first ever space-based instrument to monitor air pollutants hourly across North America during daytime. It collects high-resolution measurements of ozone, nitrogen dioxide, and other pollutants, data which will revolutionize air quality forecasts.



APPENDIX C: MANAGEMENT'S COMMENTS

National Aeronautics and Space Administration

Mary W. Jackson NASA Headquarters
Washington, DC 20546-0001

Reply to Attn of: Science Mission Directorate

TO: Acting Assistant Inspector General for Audits

FROM: Associate Administrator for Science Mission Directorate

SUBJECT: Agency Response to OIG Draft Report, "NASA's Earth System Science Pathfinder Program" (A-22-13-00-SARD)

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "NASA's Earth System Science Pathfinder Program" (A-22-13-00-SARD), dated July 21, 2023.

In the draft report, the OIG identified major weaknesses in project management, mission design and operations, and instrument development in several selected projects. Additionally, the OIG determined that NASA did not adequately vet Principal Investigators (PIs) during the solicitation phase to ensure they had appropriate project management and contracting experience, as well as sufficient time dedicated to adequately manage their projects. The OIG makes eight recommendations to the Associate Administrator for the Science Mission Directorate (SMD) intended to improve NASA's management of its Earth System Science Pathfinder (ESSP) Program.

Specifically, the OIG recommends the following:

Recommendation 1: Develop an improved methodology to ensure subject matter expertise from the ESSP Program is better incorporated during the AO process to help mitigate technical, cost, and schedule risks while averting conflicts of interest.

> **Management's Response:** NASA non-concurs. SMD is constantly striving to improve its Announcement of Opportunities (AOs) and their evaluation processes, and as a part of this continuous improvement, SMD always works to incorporate the expertise that may be found in program offices from individuals unaffiliated with the ESSP Program Office. Although programs offices are extensions of Headquarters, the majority of NASA programs are located at NASA Centers. NASA Centers are proposers and competitors in AO competitions. Participation of program offices in the AO evaluation and selection process as evaluators may give rise to the appearance of potential bias and conflict of interest.

To uphold the public's trust and maintain confidence in the integrity of the AO process, SMD will continue its policy of limiting the engagement of program offices in the review of proposals submitted to AOs and will continue to limit the involvement of program offices in the formulation of selection recommendations.

Estimated Completion Date: N/A

Recommendation 2: Reexamine its selection process to ensure PIs or their teams have sufficient experience, including project management and the ability to dedicate necessary resources to effectively manage ESSP projects.

Management's Response: NASA concurs. The SMD selection process currently includes the examination of the proposed project leadership team, which is led by the PI and includes the project manager and other project leaders for experience and expertise along with science, science implementation, and technical, management, and cost factors. SMD will review and modify, if necessary, its standard AO templates and processes to ensure the experience, capability, and capacity of the project leadership team and management organizations are appropriately factored into the evaluation and selection process, including discussions held at the Categorization Committee, Steering Committee, and Selection Board. These actions will be completed before the release of the next Earth Venture (EV) AO no earlier than fiscal year (FY) 2025.

Estimated Completion Date: September 30, 2024.

Recommendation 3: Reissue and require SMD stakeholders to follow the tenets of the 2017 Decision Memorandum on Class D missions (Class D Tailoring/Streamlining Decision Memorandum, December 7, 2017).

Management's Response: NASA concurs. SMD periodically provides updated guidance for Class D missions. An update was made in 2019, and the next guidance update is currently in the formal review process. SMD will reissue the updated guidance once it clears the formal review process.

Estimated Completion Date: December 19, 2023.

Recommendation 4: In collaboration with NASA's Launch Services Program, develop a process to engage early and evaluate alternative launch options if ESSP projects encounter access to space issues.

Management's Response: NASA partially concurs. The Earth Science Division's (ESD) definition of access to space encompasses launch services as well as either a hosting arrangement or a dedicated spacecraft dependent on the terms of the AO and resulting selection. Thus, access-to-space acquisitions may or may not be obtained through NASA's Launch Services Program (LSP). When there is a launch acquisition issue, ESD will work with LSP to ensure mission goals are met. In the cases where launch acquisitions are obtained through external launch providers (e.g., commercial industry, other Government agencies), ESD will consult LSP in an advisory capacity with

the understanding that any assistance may be limited due to the contractual relationships with the external launch providers. NASA will continue to monitor the commercial hosting market and include the risks of hosting in its assessments of mission feasibility.

Estimated Completion Date: November 30, 2023.

Recommendation 5: Conduct a lessons learned review of the GeoCarb mission to identify what NASA, PI, and contractor practices and activities should be revised and applied to the management of future Earth Venture Class Projects.

Management's Response: NASA concurs. Lessons learned from the Geostationary Carbon Cycle Observatory (GeoCarb) Mission will be gathered and documented as part of the overall mission closeout activity. An overall lessons learned review will be planned for after the completion of the closeout activity and will document those lessons for consideration in the management of EV Projects.

Estimated Completion Date: September 30, 2024.

Recommendation 6: Develop a plan to provide PIs and their teams with contract and project management training post-selection approval to better equip them to manage subcontractors.

Management's Response: NASA partially concurs. SMD will evaluate options for ensuring that selected PI-led teams have access to the information they need to be successful in contract and project management. In addition, the ESSP Program Office will continue to provide PI-led teams with expertise in NASA processes tailored to the appropriate risk posture.

Estimated Completion Date: April 30, 2024.

Recommendation 7: Develop formal and clear guidance on the roles, responsibilities, and expectations for the inclusion of applications within Earth Venture Class Projects.

Management's Response: NASA concurs. NASA will clarify recommendations to consistently include applications in AOs and the subsequent review process. These actions will be completed before the release of the next EV AO no earlier than FY 2025.

Estimated Completion Date: September 30, 2024.

Recommendation 8: Develop a methodology for funding applications in Earth Venture Class projects.

Management's Response: NASA partially concurs. Over the past several decades, NASA has increasingly recognized the real and substantial benefits to society through Earth science applications. While the draft report states applications are only "nominally" considered in the selection process, NASA notes that the Earth Venture Instrument Multi-Angle Imager for Aerosols investigation was selected because of the

application's outcomes for human health. In addition, the Earth Venture Mission Cyclone Global Navigation Satellite System and Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats investigations were selected because of the potential improvements to forecasts of hurricane intensity and track. Nevertheless, NASA agrees there is fundamentally more we can do.

In response to the National Academies 2017 Decadal Survey, ESD is making organizational and management changes in its approach to applications as part of its emerging "Earth Science to Action" strategy. This will connect research and application frameworks so that societal needs are considered more directly to make all Earth science activities more impactful, including enhancing and enabling applications. In response to the findings in this OIG draft report, which includes in part, this recommendation and based on the lessons learned from AOs and missions, ESD is developing a more rigorous process to ensure that applications are better understood as a NASA priority by both proposers and NASA staff, so that applications are included as key elements of proposed Venture class projects and our mission funding encompasses the full range from Earth system science to applications.

Most importantly, our processes are being revised and codified in our ESD Handbook to define the responsibilities and authority of the Headquarters management team to ensure that applications are included in AO development, review, and selection criteria, with expanded criteria planned for future AOs. The Program Level Requirements Appendix, which is the primary document guiding mission development and defining success criteria, will be expected to include specific application requirements. A specific Program Applications Lead will be assigned to all AOs to ensure that these new protocols are followed. Finally, ESD will ensure that applications are specifically considered in life-cycle reviews. We anticipate that these approaches will result in greater and more impactful application outcomes because they will be built into the selection, in line with the recommendation.

Estimated Completion Date: April 30, 2024.

We have reviewed the draft report for information that should not be publicly released. As a result of this review, we have identified information (provided separately) that we believe should not be publicly released.

Once again, thank you for the opportunity to review and comment on the subject draft report. If you have any questions or require additional information regarding this response, please contact Peter Meister at (202) 358-1557.

Nicola J. Fox

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Dr. Nicola Fox
Associate Administrator for the
Science Mission Directorate

APPENDIX D: REPORT DISTRIBUTION

National Aeronautics and Space Administration

Administrator
Deputy Administrator
Associate Administrator
Deputy Associate Administrator
Chief of Staff
Chief Program Management Officer
Chief Scientist and Senior Climate Advisor
Associate Administrator for Science Mission Directorate
Earth Science Division Director
Associate Director for Flight Programs, Earth Science Directorate
Earth System Science Pathfinder Program Manager

Non-NASA Organizations and Individuals

Office of Management and Budget
    Deputy Associate Director, Climate, Energy, Environment and Science Division

Government Accountability Office
    Director, Contracting and National Security Acquisitions

Lockheed Martin Corporation

Raytheon Technologies Corporation

Representatives from 21 active ESSP projects

Congressional Committees and Subcommittees, Chairman and Ranking Member

Senate Committee on Appropriations
    Subcommittee on Commerce, Justice, Science, and Related Agencies

Senate Committee on Commerce, Science, and Transportation
    Subcommittee on Space and Science

Senate Committee on Homeland Security and Governmental Affairs

House Committee on Appropriations
    Subcommittee on Commerce, Justice, Science, and Related Agencies

House Committee on Oversight and Accountability
    Subcommittee on Government Operations and the Federal Workforce

House Committee on Science, Space, and Technology
    Subcommittee on Investigations and Oversight
    Subcommittee on Space and Aeronautics

(Assignment No. A-22-13-00-SARD)