



NASA OFFICE OF INSPECTOR GENERAL

OFFICE OF AUDITS
SUITE 8U71, 300 E ST SW
WASHINGTON, D.C. 20546-0001

March 13, 2017

TO: Thomas Zurbuchen
Associate Administrator for the Science Mission Directorate

SUBJECT: Final Memorandum, *Earth Venture Suborbital Investigations*
(IG-17-013; A-16-019-00)

Dear Associate Administrator Zurbuchen,

The Office of Inspector General (OIG) evaluated NASA's Earth Venture Suborbital (EVS) investigations to assess whether they were meeting science objectives, adhering to established cost caps, and using the most appropriate platform to perform their research.¹ See Enclosure I for details of the audit's scope and methodology, our review of internal controls, and prior audit coverage on this and related issues.

We concluded the first five EVS investigations (collectively known as EVS-1) NASA completed between fiscal years 2010 and 2016 were well managed, achieved their science requirements within the applicable \$30 million threshold, and used the appropriate research platform. Further, as a result of lessons learned during EVS-1, the Agency changed how it administered the six EVS-2 investigations in ways that should strengthen the management and oversight of EVS investigations.

BACKGROUND

Climate, weather, and other natural phenomena such as earthquakes, droughts, floods, and wildfires affect the health and wellbeing of every person on Earth. Moreover, industries vulnerable to these events, including agriculture, insurance, real estate, and manufacturing, account for up to 40 percent of

¹ Investigations may gather data from observation platforms such as aircraft, balloons, or other vehicles capable of reaching suborbital space; land and sea-based facilities; and existing satellite missions. Each EVS investigation we reviewed proposed the use of an aircraft as one of its primary observation platforms.

the U.S. economy, or about \$7.2 trillion in 2015.² As we reported in a November 2016 report, NASA’s space-based Earth science observations play an important role in planning for and mitigating the deleterious impacts of extreme weather and other natural phenomena.³

In 2004, NASA, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey requested the National Research Council (NRC) conduct the first Earth Science Decadal Survey to identify research priorities for NASA, NOAA, and the scientific community. To conduct the Survey, the NRC convened a committee of experts from 68 Government, academic, and commercial institutions and reviewed 135 proposals from the science community. In its 2007 Decadal Survey, the NRC recommended NASA pursue 15 specific Earth science missions based on criteria that included scientific merit, societal benefit, affordability, readiness, risk level, and fit with other missions.⁴ In addition, the NRC recommended NASA create a new “Venture class” of missions that the NRC described as cost-effective, innovative missions focusing on establishing new research avenues or demonstrating key application-oriented measurements. According to the NRC, the success of these missions was dependent on maintaining a steady stream of opportunities for community participation in the development of innovative ideas while enforcing strict schedule and cost guidelines for program participants.

NASA’s Earth Venture Class Project

In response to the 2007 Decadal Survey, the NASA Science Mission Directorate created the Earth Venture Class Project to conduct low-cost Earth science research and application missions to demonstrate innovative ideas and higher-risk technologies and provide training for future leaders of space-based observations for Earth science applications.

Part of the Science Mission Directorate, NASA’s Earth Science Division is composed of four components – the Flight Program, the Research and Analysis Program, the Applied Sciences Program, and the Earth Science Technology Office.⁵ The Flight Program is responsible for development and operation of Earth science satellites and instruments and is comprised of the Earth Systematic Mission Program and the Earth System Science Pathfinder (ESSP) Program, the latter of which is responsible for administering the Earth Venture class of missions.⁶

² In 2010, the National Research Council calculated that up to 40 percent of the U.S. economy was weather and climate related, an estimate that has not been subsequently updated. We applied the 2010 percentage calculated by the National Research Council to the 2015 Gross Domestic Product (GDP) as reported by the U.S. Department of Commerce, Bureau of Economic Analysis, to estimate the amount of the GDP potentially impacted by climate and weather.

³ NASA Office of Inspector General, “NASA’s Earth Science Mission Portfolio” (IG-17-003, November 2, 2016).

⁴ NRC, “Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond,” 2007.

⁵ The Research and Analysis Program and the Applied Sciences Program oversee and fund the Earth Science Division’s effort to make Earth observation data understandable to and useful for researchers and the public. The Earth Science Technology Office portfolio includes more than 100 investments in advanced technologies to enable new Earth science measurements, missions, operational requirements, and practical applications.

⁶ The Earth Systematic Mission Program manages the largest of NASA’s Earth science missions, including Aqua – launched in May 2002 to study Earth’s water cycle; Terra – launched in December 1999 to study Earth’s atmosphere, ocean, land, snow, and ice; and Landsat 8 – launched in February 2013 to continue the more than 40-year coverage of continental Earth surfaces provided by the joint NASA and U.S. Geological Survey Landsat Program.

The ESSP Program, managed from the Langley Research Center, supports Earth science research by periodically soliciting proposals and competitively selecting investigations to achieve NASA's scientific goals and priorities. ESSP projects include development and operation of space missions, space-based remote sensing instruments, and airborne science missions, and often involve partnerships with other U.S. or international science and space organizations. The ESSP Program supports relatively low to moderate cost, small to medium-sized principal investigator-led missions capable of being built, tested, and launched in a relatively short time.⁷ For each mission, the principal investigator must provide the raw data and analysis of the research to a database accessible to the public, issue publications based on the research, conduct public outreach, and document lessons learned.

The Earth Venture Class Project supports ESSP's activities through regularly solicited, competitively selected Earth science investigations with cost caps varying between \$30 and \$150 million.⁸ The Project consists of three activities:

- *Small Missions* include the development and operation of space missions capped at \$150 million per project. For example, in 2012 NASA selected the Cyclone Global Navigation Satellite System, a constellation of eight small satellites launched in 2016 to improve prediction of extreme weather events like hurricanes.
- *Instruments* include the development of flight-ready, space-based remote sensing instruments capped at \$90 million. For example, in 2012 NASA selected the Tropospheric Emissions: Monitoring of Pollution instrument planned to be hosted on a commercial satellite and launched no later than 2021 to measure atmospheric pollution over most of North America.
- *Suborbital Investigations* include airborne science missions capped at \$30 million. In February 2009 and again in February 2013, NASA solicited the science community for proposals for suborbital investigations and selected 11 for development.

Earth Venture Suborbital Investigations

NASA competitively selects EVS investigations through solicitations that occur every 4 years. Each solicitation has a \$150 million (fiscal year 2014 dollars) cost cap divided among the selected projects. While NASA may award each project no more than \$30 million, projects may receive additional funds from other sources. In addition, each investigation must be completed within 5 years. Along with these cost and life-cycle constraints, investigations must advance Earth system science objectives through regional or larger scale measurements over time that are sufficient to prove or disprove a scientific hypothesis or address scientific questions. In addition, they must use mature system technology – meaning that, at a minimum, a system, subsystem model, or prototype demonstration has taken place in a relevant environment with a technology readiness level of 6 or greater.⁹

⁷ A principal investigator is a person who conceives of and is responsible for carrying out an investigation. In some cases, principal investigators from industry and academia act as project managers for smaller development efforts with NASA personnel providing oversight.

⁸ Fiscal year 2014 dollars. NASA subsequently increased the cost cap for Earth Venture Small Mission and Instrument solicitations to \$166 million and \$97 million in fiscal year 2018 dollars, respectively.

⁹ Technology readiness levels assess the maturity of technology. NASA's scale consists of nine technology readiness levels ranging from level 1, when scientific research is beginning and results are being translated into future research and development, to level 9, when the technology is flight proven. A technology readiness level 6 occurs once testing is completed and the technology has a fully functional prototype or representational model.

EVS investigations are led by principal investigators who submit proposals to NASA for consideration, including their view of the most appropriate platform for their investigation, and manage the cost, schedule, and performance of the work. Principal investigators select their project teams, which may include representatives from universities, industry, government, federally funded research and development centers, and foreign space agencies or other foreign partners.

The Science Mission Directorate convenes two review panels comprised of subject matter experts and Earth Science Division officials to assess EVS proposals for scientific merit, cost, schedule feasibility, and appropriateness.¹⁰ The review panels, together with officials from NASA's Airborne Science Program, also assess the proposed platforms for each investigation and after award may suggest the use of alternative aircraft based on project needs and aircraft availability.¹¹

In February 2009 and February 2013, the Science Mission Directorate solicited proposals for EVS-1 and EVS-2 investigations, respectively.¹² These solicitations requested proposals for complete suborbital, principal investigator-led investigations to conduct innovative, integrated, hypothesis or scientific question driven approaches to important Earth system science issues. Five investigations were selected for EVS-1 and six for EVS-2. All EVS-1 investigations had been completed at the time of our fieldwork, while EVS-2 investigations, which began in fiscal year 2015, had completed their first year of effort.

EARTH VENTURE SUBORBITAL INVESTIGATIONS ARE MEETING REQUIREMENTS

We found all five EVS-1 investigations completed their proposed missions within the cost caps set by the Science Mission Directorate and Earth Science Division. Each investigation provided the raw data and analysis from each flight campaign to a database accessible to the public, issued numerous publications, provided outreach activities, and documented lessons learned. With regard to EVS-2 investigations, we found that post-selection aircraft changes appeared to be reasonable and that management applied lessons learned from EVS-1 to the EVS-2 process. Because the EVS-2 investigations are in the early stages, we could not determine whether they will achieve their science objectives or remain within the \$30 million cost threshold.

¹⁰ One review panel examines the science and the other the technical, management, logistics, and cost aspects of the proposal.

¹¹ The Airborne Science Program is part of the Earth Science Division and provides suborbital flight opportunities and manages NASA's airborne asset schedules.

¹² The next solicitation, EVS-3, is planned for release in 2017.

EVS-1 Investigations

For EVS-1, NASA selected the following 5 proposals from a total of 35 received.

Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS). A principal investigator from the University of Michigan, who subsequently transferred to the University of Southern California, led this \$25,805,028 investigation. The goal of AirMOSS was to reduce uncertainties in existing greenhouse gas estimates by measuring soil moisture in the root zone of major North American ecosystems. The investigation used NASA's Gulfstream-III aircraft and validated root-zone soil measurement algorithms from NASA's Soil Moisture Active and Passive mission.¹³

Airborne Tropical Tropopause Experiment (ATTREX). A principal investigator from Ames Research Center led this \$29,178,214 investigation to study how stratospheric water vapor impacts Earth's climate, ozone layer, and how much solar energy the Earth retains. The principal investigator proposed to fill several significant gaps in atmospheric science identified in the 2007 Decadal Survey involving climate change, stratospheric ozone, and stratosphere-troposphere exchange. ATTREX used NASA's Global Hawk unmanned aircraft system.

Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE). A principal investigator from the Jet Propulsion Laboratory led this \$27,866,347 investigation to collect detailed measurements of greenhouse gases in the Alaskan Arctic and demonstrate new remote sensing and improved modeling capabilities to quantify Arctic carbon fluctuations and carbon cycle-climate processes. The principal investigator proposed using a commercial Twin Otter aircraft because NASA did not have an aircraft capable of meeting the investigation's requirements. This aircraft was used during the first year of flight operations, but the project later switched to a C-23 Sherpa twin-engine aircraft turboprop NASA acquired from the Department of Defense. Airborne Science Program officials stated that the C-23 was a better fit for operating in the Arctic considering crew rest needs as it allows for an additional onboard operator compared to the Twin Otter aircraft.

Deriving Information on Surface Conditions from Column and Vertically Resolved Observations

Relevant to Air Quality (DISCOVER-AQ). A principal investigator from the Langley Research Center led this \$31,058,059 investigation (\$29,983,969 funded by NASA, approximately \$600,000 by the University of Innsbruck, and \$467,556 by the National Center for Atmospheric Research) to study such air quality factors as aerosols and ozone-producing gases and their effects on society.¹⁴ DISCOVER-AQ provided an opportunity to improve the existing knowledge gap that limits the utility of satellite observations for air quality. DISCOVER-AQ used NASA's B-200 Beechcraft Super King Air aircraft and P-3B four-engine turboprop aircraft.

¹³ Launched in January 2015, the Soil Moisture Active and Passive mission is designed to produce global maps of soil moisture to help scientists understand how water and carbon circulate around the Earth.

¹⁴ The National Center for Atmospheric Research and the University of Innsbruck funded portions of investigators' labor needed to participate in the mission.

Hurricane and Severe Storm Sentinel (HS3). A Goddard Space Flight Center principal investigator led this \$29,984,528 investigation to study hurricane activity in the Atlantic Ocean basin and collect information that could be beneficial in predicting formation and forecasting intensity changes. During the 2012 through 2014 hurricane seasons, the investigation flew missions covering nine named storms, six of which were hurricanes. Initially, the principal investigator proposed using the Agency's two Global Hawk unmanned aircraft systems; however, technical problems with one of the aircraft resulted in the investigation using only one Global Hawk along with the WB-57 high altitude aircraft.

EVS-2 Investigations

For EVS-2, NASA selected the following 6 proposals from a total of 33 received.

Atmospheric Carbon and Transport-America (ACT-America). A principal investigator from The Pennsylvania State University is leading this investigation budgeted at \$29,992,000 to study greenhouse gases by quantifying the sources of regional carbon dioxide, methane, and other gases and documenting how weather systems transport these gases in the atmosphere. Initially, the investigation planned to use the Agency's P-3B and B-200 aircraft; however, the Airborne Science Program changed aircraft because three other investigations had requested use of the P-3B aircraft. The investigation now plans to use a C-130 four-engine turboprop aircraft.

Atmospheric Tomography (ATom). A Harvard University principal investigator is leading this investigation budgeted at \$29,852,000 to study the impact of human-produced air pollution on certain greenhouse gases. Airborne instruments will look at how atmospheric chemistry was transformed by various air pollutants and the impact of methane and ozone which affect climate. Data from ATom should help form the scientific foundation for near term mitigation strategies by systematically measuring reactive gases and aerosols spanning the Pacific and Atlantic Oceans. The plans are to use NASA's DC-8 jet aircraft.

Coral Reef Airborne Laboratory (CORAL). A Bermuda Institute of Ocean Sciences' principal investigator is leading this investigation budgeted at \$15,000,000 to study the condition of threatened coral reef ecosystems in Florida, Hawaii, the Mariana Islands, Australia, and Palau by analyzing how the environment shapes the reef ecosystem. The investigation plans to use a Gulfstream-IV commercial aircraft, which is able to cover large areas of regional reef systems and the long distances between those systems.

North Atlantic Aerosols and Marine Ecosystems Study (NAAMES). A principal investigator from Oregon State University is leading this investigation budgeted at \$29,960,000 to study the annual life cycle of phytoplankton and the impact small airborne particles derived from marine organisms have on climate in the North Atlantic Ocean. Data from NAAMES will be used to inform ocean management activities and assessments of ecosystem changes. The investigation planned to use NASA's P3-B aircraft; however, due to overlapping needs, NAAMES will use the Agency's C-130 aircraft. NAAMES will also use the research vessel *Atlantis* – a U.S. Navy ship operated out of the Woods Hole Oceanographic Institution.

Observations of Aerosols above Clouds and their Interactions (ORACLES). A principal investigator from Ames Research Center is leading this investigation budgeted at \$29,971,000 to probe how smoke particles from biomass burning in Africa influence cloud cover over the Atlantic Ocean.¹⁵ The investigation plans to use NASA's P-3B and ER-2 high altitude sensor aircraft.

Oceans Melting Greenland (OMG). A principal investigator from the Jet Propulsion Laboratory is leading this investigation budgeted at \$29,596,000 to study the role warmer, saltier Atlantic Ocean subsurface waters play in Greenland glacier melting. Data from OMG should provide improved estimates of sea level rise. The investigation proposed a ship-based survey of sea floor depth and shape along with an airborne campaign using NASA's P-3B aircraft, but the P-3B was being used by other projects. The Airborne Science Program has identified the Agency's Gulfstream-III aircraft as an alternative.

Changes Made To Improve EVS-2 Administration

For EVS-1 investigations, the ESSP Program used program and project management criteria applicable to development of space flight projects and their supporting instrument and technology – NASA Procedural Requirements (NPR) 7120.5E – that calls for numerous structured reviews for assessing progress.¹⁶ However, ESSP Program management determined this criteria was not well suited to their needs because EVS investigations utilize research instruments at technology readiness levels of 6 or greater and the standard reviews required by NPR 7120.5E were unnecessary. Accordingly, for EVS-2 ESSP Program management began using the criteria applicable to managing research and technology efforts – NPR 7120.8 – which provides greater flexibility in implementing management processes and ensuring suborbital investigation success.¹⁷ With this change, pre-deployment management reviews were reduced to one confirmation review that focuses on whether the investigation is achieving its Level 1 science requirements within cost and schedule constraints and is technically ready to proceed to implementation.¹⁸

In addition, for EVS-2 investigations the ESSP Program required that principal investigators and project scientists draft project implementation plans incorporating the traditional elements of a project plan, including Level 1 science requirements and data management and safety plans, which provided an additional element of control for ESSP Program managers.

The ESSP Program also used grants rather than contracts to fund the four non-NASA led EVS-2 investigations. This decision was made based on the Program's experience with the non-NASA led EVS-1 investigation.¹⁹ Specifically, based on that experience the Program learned that educational institutions are more accustomed and therefore better equipped to conform to the requirements of Federal grant instruments rather than Federal contracts.

¹⁵ The Aerosol Robotic Network is a federation of ground-based remote sensing aerosol networks established by NASA and international collaborators from national agencies, institutes, universities, individual scientists, and partners to provide a long-term, continuous and readily accessible public domain database of aerosol optical, microphysical and radiative properties for aerosol research and characterization, validation of satellite data, and synergism with other databases.

¹⁶ NPR 7120.5E, "NASA Space Flight Program and Project Management Requirements," August 14, 2012.

¹⁷ NPR 7120.8, "NASA Research and Technology Program and Project Management Requirements," February 5, 2008.

¹⁸ Level 1 requirements are the fundamental and basic set of requirements levied by the ESSP Program on the investigation.

¹⁹ The ESSP Program's decision is also supported by the NASA Grant and Cooperative Agreement Manual.

Finally, for EVS-2 the ESSP Program directed principal investigators to issue publications at appropriate points during the course of investigations rather than waiting for the conclusion of the entire project to enable the public more timely access to data.

Although this memorandum made no specific recommendations to NASA, management provided a brief response that is reproduced in Enclosure II. Technical comments provided by management have been incorporated, as appropriate.

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

Sincerely,

A handwritten signature in black ink, appearing to read "PKMA". The letters are stylized and connected, with a large "P" and "K" at the beginning and "M" and "A" at the end.

Paul K. Martin
Inspector General

cc: Krista Paquin
Associate Administrator, Mission Support Directorate

Michael H. Freilich
Director, Earth Science Division

Eugene L. Tu
Director, Ames Research Center

Christopher J. Scolese
Director, Goddard Space Flight Center

Michael Watkins
Director, Jet Propulsion Laboratory

Dave Bowles
Director, Langley Research Center

Enclosures – 2

Enclosure I: Scope and Methodology

We performed this audit from September 2016 through February 2017 in accordance with generally accepted government auditing standards, which require that we plan and perform the review to obtain sufficient, appropriate evidence to provide a reasonable basis for findings and conclusions based on our objectives. We believe the evidence obtained provides a reasonable basis for our conclusions based on our objectives.

In September 2016, we began work to determine whether EVS investigations were meeting their science objectives, Agency costs did not exceed \$30 million for each investigation, and the investigations were using the most appropriate platform for their research requirements. We engaged with ESSP Program personnel to confirm the primary scientific focus of the EVS-1 and EVS-2 investigations. Other discussions with ESSP personnel pertained to the historical and background data of the EVS investigations and their alignment with NRC recommendations.

We compared EVS-1 proposals to program-level requirements and investigation success criteria to determine what research NASA authorized for each investigation. We reviewed final presentations and ESSP and Earth Science Division assessments of the final presentations to validate EVS-1 investigations achieved their scientific objectives.

We coordinated with ESSP personnel and EVS-1 principal investigators to obtain the costs of each investigation for their periods of performance. To determine whether each investigation stayed under its cost cap, we reviewed the obligated, costed, and disbursed funds for each EVS-1 investigation and held discussions with the EVS-1 principal investigators to ascertain whether they could provide cost documentation for their investigation team partners. We found that sub-award cost data was not readily available because principal investigators managed their own investigation costs and accepted costs as originally proposed by these independent team partners. We concluded there was a low risk of inappropriate use of funds based on assurance from the principal investigators that partners stayed within proposed budgets and results of investigations were consistent with what was proposed and expected.

To determine whether EVS-1 and EVS-2 investigations used the most appropriate platforms, we reviewed and compared the project proposals, project plans, and project closeout documentation. We also interviewed Airborne Science Program officials to discuss the process used to select platforms and found appropriate assignments and, when required, changes due to aircraft availability. We did not complete an assessment on the use of ships to complete research.

We reviewed lessons learned briefed during the final presentations and determined administrative changes implemented by ESSP were advantageous in that they focused investigators on meeting cost and schedule commitments and achieving Level 1 science requirements within an acceptable risk level.

Use of Computer Processed Data

We used computer processed data to conduct this audit. We conducted an Internet search to identify EVS-1 and EVS-2 investigations prior to contacting ESSP Program personnel for identification of audit universe, historical, background, and financial data. We obtained proposal and financial data the principal investigators provided directly to the ESSP Program Office, which was not specifically validated, but accepted as provided due to our assessment of a low risk of improper spending. We also relied on

various management reviews and the principal investigators' final investigation submissions to determine that goals and objectives were met. We determined the information obtained was sufficiently reliable to meet the objectives of our audit.

Review of Internal Controls

We evaluated internal controls, organizational structures, and policies for the Earth Science Division, ESSP Program Office, Airborne Science Program, and EVS-1 principal investigators for the AirMOSS, ATTREX, CARVE, DISCOVER-AQ, and HS3 investigations that (1) provided reasonable assurance these investigations met their Earth Venture objectives, (2) safeguarded resources, and (3) provided relevant and reliable data to the public. We concluded that internal controls were generally adequate.

Prior Coverage

During the last 5 years, the Government Accountability Office did not issue any reports specifically relevant to our audit objectives. We reviewed a recent NASA Office of Inspector General (OIG) report, *NASA's Earth Science Mission Portfolio* (IG-17-003, November 2, 2016), which assessed NASA's management of 69 Earth science missions, to acquire background information on Earth Venture investigations. OIG audit reports can be accessed at <http://oig.nasa.gov/audits/reports/FY17>.

Enclosure II: Management Comments

National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-0001



MAR 9 2017

Reply to Attn of:

Science Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator

SUBJECT: Agency Response to OIG Draft Memorandum, "Earth Venture Suborbital Investigations" (A-16-019-00)

Thank you for the opportunity to review and comment on the Office of Inspector General (OIG) draft memorandum entitled "Earth Venture Suborbital Investigations" (A-16-019-00), dated February 22, 2017.

NASA appreciates and values the effort expended by the OIG during the course of this investigation.

While the draft memorandum contains no specific recommendations to NASA, we would like to thank the OIG for recognizing that the five Earth Venture Suborbital (EVS) investigations (known collectively as EVS-1) were well managed, achieved their science requirements, and were completed within their cost caps. In addition, we appreciate that the memorandum highlights that results of lessons learned during EVS-1 were incorporated, changing how the six EVS-2 investigations are administered, strengthening and managing their oversight.

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

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

A handwritten signature in black ink, appearing to read "Thomas Zurbuchen".

Thomas Zurbuchen