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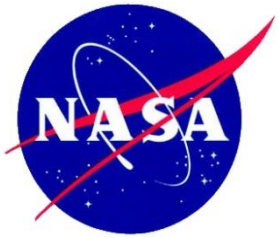
NASA's Management of the Earth Science Disasters Program

June 14, 2022

Report No. IG-22-013



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RESULTS IN BRIEF

NASA's Management of the Earth Science Disasters Program

June 14, 2022 IG-22-013 (A-21-014-00)

WHY WE PERFORMED THIS AUDIT

In 2021, the United States experienced a historic year for weather and climate disasters—20 separate billion-dollar events in total—including hurricanes that left millions of people without power, tornadoes that destroyed homes throughout the Midwest, and wildfires that raged across the Western states. Taken together, these disasters resulted in the deaths of 688 people and cost the nation a combined $145 billion in damages.

With the number of major disasters increasing throughout the world, NASA's Earth Science Disasters Program (ESDP) is focused on using space- and ground-based observations to provide disaster-related data and information products to domestic and international partners and stakeholders. These products promote global disaster resilience—that is, the ability of nations and communities to prevent, withstand, adapt to, and recover from the harmful impacts of adverse events on people, places, and the natural environment. NASA's Earth Science Division's (ESD) Applied Sciences Program (ASP) initially provided disaster response support on an ad-hoc basis, but in 2016 ESDP was formalized as a program under ASP.

In this audit we assessed NASA's management of ESDP, specifically whether the Agency effectively (1) provides data and information products to predict, prepare for, respond to, and recover from disasters and (2) evaluates the output and outcomes of its efforts to assist entities with disasters. To complete this work, we interviewed ESDP officials and conducted two surveys, one of NASA Center disaster coordinators and one of ESDP partners and stakeholders. We also reviewed the NASA Disasters Mapping Portal website and federal and NASA criteria, policies, and procedures, and evaluated ESDP reports, guidance documents, and after-action assessments.

WHAT WE FOUND

ESDP effectively collects and distributes relevant imagery, data products, and damage assessments to domestic and international partners and stakeholders to predict, prepare for, respond to, and recover from disasters. ESDP reported 40 disaster activations in 2021 and has provided products such as color maps for flood disasters; infrared color products for earthquakes; wildfire-related air quality maps; and data and imagery on lava flow, ashfall, and damage for volcanic eruptions. However, the Program struggles to do so efficiently because ESD and ASP leadership has not created, in collaboration with the ESDP Program Manager, a strategic plan or requirements document to outline the Program's mission, goals, and objectives. We believe the Program could benefit from applying Agency policy requirements to develop a project plan like those in NASA Procedural Requirements (NPR) 7120.8A and finalizing the NASA Disasters Multi-Year Strategic Plan (2018-2022), which ESDP developed in 2018 but remains in draft due to staffing limitations, lack of feedback from ESD leadership, and lack of prioritization within the Program. Lack of clear and consistent communication from ESD and ASP leadership about ESDP's priorities has also created a disconnect regarding Program expectations, goals, and objectives.

NASA is required by the Robert T. Stafford Disaster Relief and Emergency Assistance Act to assist the federal government in responding to disasters, but because the Agency is not reimbursed for this work unlike other federal agencies named

in the Act, the Program is challenged given its limited resources and infrastructure to efficiently carry out its mission. ESDP's $6.5 million budget has remained relatively flat the past 5 years, and the staff consists of 5 full-time employees and 18 part-time disaster coordinators who dedicate about 5 to 75 percent of their time to ESDP activities. As a result, we found ESDP's budget and personnel resources inadequately allocated to scale support, ensure continuity, and maintain sustainable disaster response support.

Guidance for providing disaster support is also incomplete and inconsistently used by ESDP staff. For example, the NASA Disasters Program Playbook—initially developed in 2016—provides ESDP personnel standard operating procedures and guidance on tasks, expectations, and responsibilities for disaster response support activities and is crucial to the Program's day-to-day activities. Although established as a Program requirement in its draft Strategic Plan, the Playbook is incomplete and, like the Strategic Plan, remains in draft. According to ESDP staff, a lack of time, resources, prioritization, and training have resulted in the Playbook being inconsistently followed. In addition, we found a lack of awareness of the Playbook's existence among some Center disaster coordinators and confusion over the expected application of the Playbook as to whether it is a flexible guide or strict set of standard operating procedures. This has created communication, prioritization, and workflow inefficiencies between ESDP employees as well as with ESD and ASP leadership.

Finally, after-action activities provide essential opportunities for ESDP to review its processes and products following a disaster activation, identify inefficiencies, and develop future improvements. NASA policy requires capturing and sharing knowledge to continuously improve performance, the draft Strategic Plan requires capturing and integrating lessons learned and improvement opportunities, and the Playbook outlines how after-action assessments should be conducted. However, due to the increasing rate and severity of disasters and limited staff, ESDP rarely completes such assessments. For example, from 2018 through 2021 ESDP assisted with 204 disasters but were only able to provide us 8 documented after-action assessments. Furthermore, documented assessments lack consistency and ESDP does not track resulting recommendations and whether improvements are implemented for disaster response. Limited and incomplete after-action activities can lead to missed opportunities for the Program to improve processes and products and enhance internal communication and collaboration.

WHAT WE RECOMMENDED

To improve NASA's management of the Earth Science Disasters Program, we recommended NASA's Associate Administrator for Science Mission Directorate direct the Earth Science Division Director to (1) establish and document Program management requirements in a strategic plan and/or NPR 7120.8A project plan format for consistent messaging on ESDP priorities, objectives, and quantifiable performance metrics; (2) perform a funding analysis of ESDP to determine if current resources are adequate to manage, oversee, and administer Program goals and objectives in accordance with its strategic plan and/or project plan; (3) coordinate with appropriate NASA offices to develop Memorandums of Understanding that facilitate reimbursement agreements with applicable federal agencies that request Agency support for disaster events; (4) require ESDP, in coordination with ASP, to finalize the NASA Disasters Program Playbook and complete associated annexes and appendixes; (5) ensure ESDP provides regular training to Center disaster coordinators regarding the Playbook and expectations of application; (6) require the ESDP Program Manager to develop a formalized plan to capture knowledge and increase the frequency of conducting after-action activities as appropriate; and (7) require the ESDP Program Manager to develop a system to track lessons learned recommendations resulting from after-action assessments to ensure the recommendations are implemented and routinely evaluated for effectiveness.

We provided a draft of this report to NASA management who concurred with our recommendations and described planned actions to address them. We consider the proposed actions responsive and will close the recommendations upon completion and verification.

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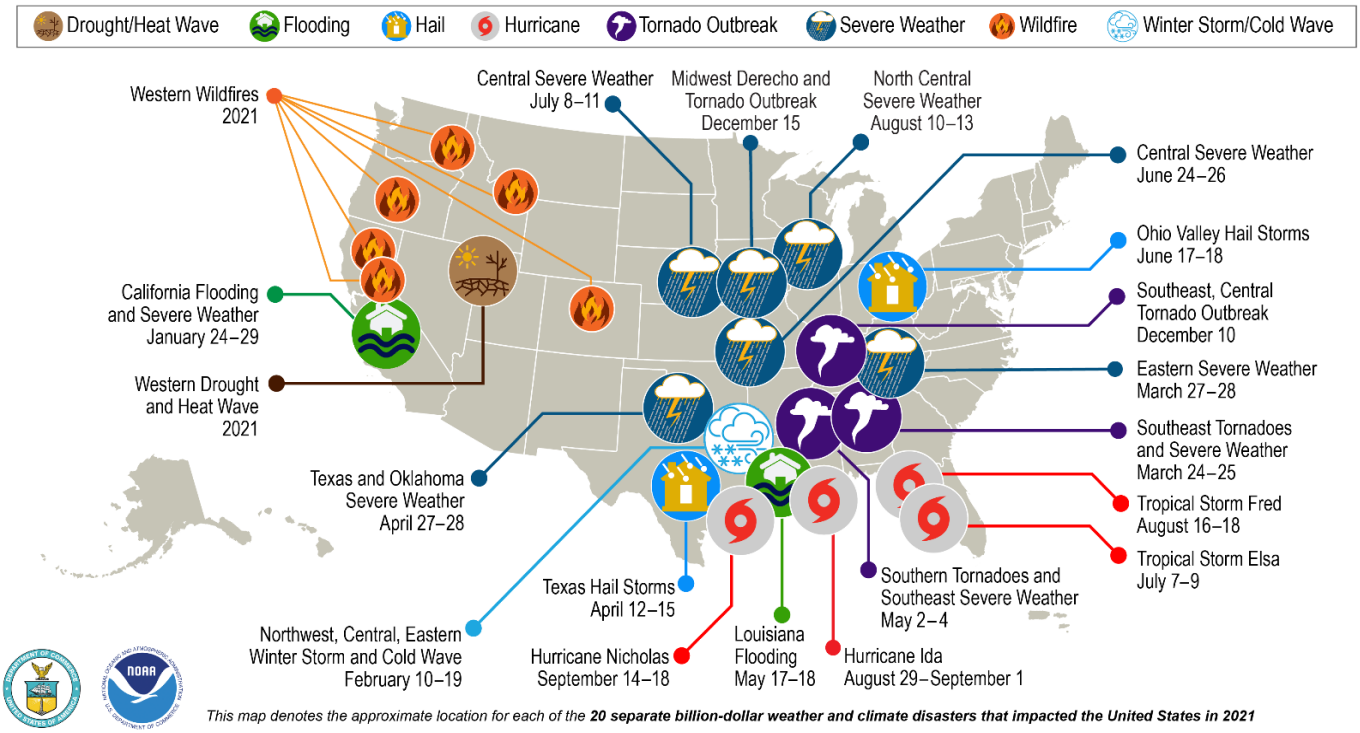
Acronyms

ASP	Applied Sciences Program
ESD	Earth Science Division
ESDP	Earth Science Disasters Program
FY	fiscal year
GIS	Geographic Information System
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
OIG	Office of Inspector General
ROSES	Research Opportunities in Space and Earth Science
RSC	Response Support and Coordination
USAID	United States Agency for International Development

INTRODUCTION

While the COVID-19 pandemic has understandably dominated headlines throughout the world for the past 2 years, 2021 was a historic year for weather and climate disasters in the United States. Over the past 40 years, 2021 ranks second as the year with the greatest number of billion-dollar weather-related disasters and third as the costliest year for such disasters. In 2021, the country experienced 20 separate billion-dollar events (as illustrated in Figure 1), including hurricanes that left millions of people without power, tornadoes that destroyed homes as they tore through the Midwest, and wildfires that raged across the American West. Added together, these disasters resulted in the deaths of 688 people and cost the nation a combined $145 billion in damages.

Figure 1: U.S. 2021 Billion-Dollar Weather and Climate Disasters



Source: National Oceanic and Atmospheric Administration.

Beyond the United States, disasters continued to impact other countries as well. For example, in August 2021 Haiti suffered a major earthquake and tropical depression within a span of days resulting in over 15,000 causalities. As part of its response to disasters, NASA's Earth Science Disasters Program (ESDP) promotes the use of Earth observations to improve the prediction of, preparation for, response to, and recovery from natural, human-caused, and technological disasters, such as industrial accidents. With the number of major disasters increasing throughout the world, ESDP is focused on providing disaster-related information and observations to domestic and international partners and stakeholders to promote global disaster resilience—that is, the ability of nations, communities, and others to prevent, withstand, adapt to, and recover from the harmful impacts of adverse events on people, places, and the

natural environment.[1] Accordingly, we conducted this audit to assess NASA's management of ESDP. Specifically, we evaluated whether the Agency effectively (1) provides data and information products to entities to predict, prepare for, respond to, and recover from disasters and (2) evaluates the output and outcomes of its efforts to assist entities with disasters. We examined ESDP guidance documents for conducting disaster responses. We also conducted two surveys, one of Center disaster coordinators and the other of ESDP partners and stakeholders, to gather information on the disaster-related data products the Program provides. See Appendix A for a full explanation of our scope and methodology.

Background

Although NASA has no federal mandate to provide primary response and coordination for disaster events, the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) requires the Agency to provide support assistance with the federal government's disaster response preparedness.[2] Within NASA's Science Mission Directorate, the Earth Science Division's (ESD) Applied Sciences Program (ASP) helps federal agencies, local governments, and communities around the world use the Agency's Earth science data to inform crucial decision-making, enhance quality of life, and strengthen economies. ASP uses NASA's space- and ground-based observations to provide support to institutions and individuals to aid them in making better decisions about their environment, food, water, health, and safety.

Beginning in 2002, ASP provided disaster response support on an ad-hoc basis. In 2016, ESDP was formalized as a program under ASP.[3] ESDP promotes the development and use of innovative applications utilizing NASA satellite mission data to improve and ensure timely support to communities and responders when disasters occur. To achieve this goal, ESDP focuses on two primary areas—application science research and disaster response support—and relies on ESDP management, officials, and staff divided into five sections—Application Research Portfolio branch, Risk Reduction and Resilience branch, Program Support branch, Response Support and Coordination (RSC) branch, and NASA Centers.[4] Leading these five sections, the ESDP Program Manager runs day-to-day operations for the Program. The Program Manager also serves on the Committee on Earth Observation Satellites and the Group on Earth Observations Disaster Risk Reduction Working Group.[5] Two Associate Program

[1] In this report, partners and stakeholders are defined in accordance with ESDP's NASA Disasters Program Playbook. Partners refer to a direct recipient, be it an individual or entity, of data products, models, and related tools who also contribute to the advancement of the Program's science objectives. Stakeholders refer to a beneficiary, in the broadest sense, and come from many areas including government, research, civil protection, education, industry, community groups, and individuals.

[2] Robert T. Stafford Disaster Relief and Emergency Assistance Act, Pub. L. No. 93-288, as amended, 42 U.S.C. 5121 et seq. The Act constitutes the statutory authority for most federal disaster response activities, especially as they pertain to the Federal Emergency Management Agency and its programs.

[3] ESDP is exploring the possibility of restructuring the Program. The information provided in this report describes the organization of ESDP as of December 2021.

[4] In this report, we interchangeably refer to the Program Manager(s) as ESDP management, ESDP Headquarters emergency management specialists as Program officials, and all other employees within the Program as ESDP staff.

[5] The Committee on Earth Observation Satellites was established in 1984 and serves as the primary forum for international coordination of space-based Earth observations. The Group on Earth Observations was established in 2005 and is an intergovernmental partnership to improve the availability, access, and use of Earth observations for a sustainable planet. Their Disaster Risk Reduction Working Group was established in 2020 to develop and implement a coherent and crosscutting approach within the organization to advance the use of Earth observations to support national disaster risk reduction and resilience efforts.

Managers provide direction and coordination to the Program; however, each has a primary focus of either application science research or disaster response support.

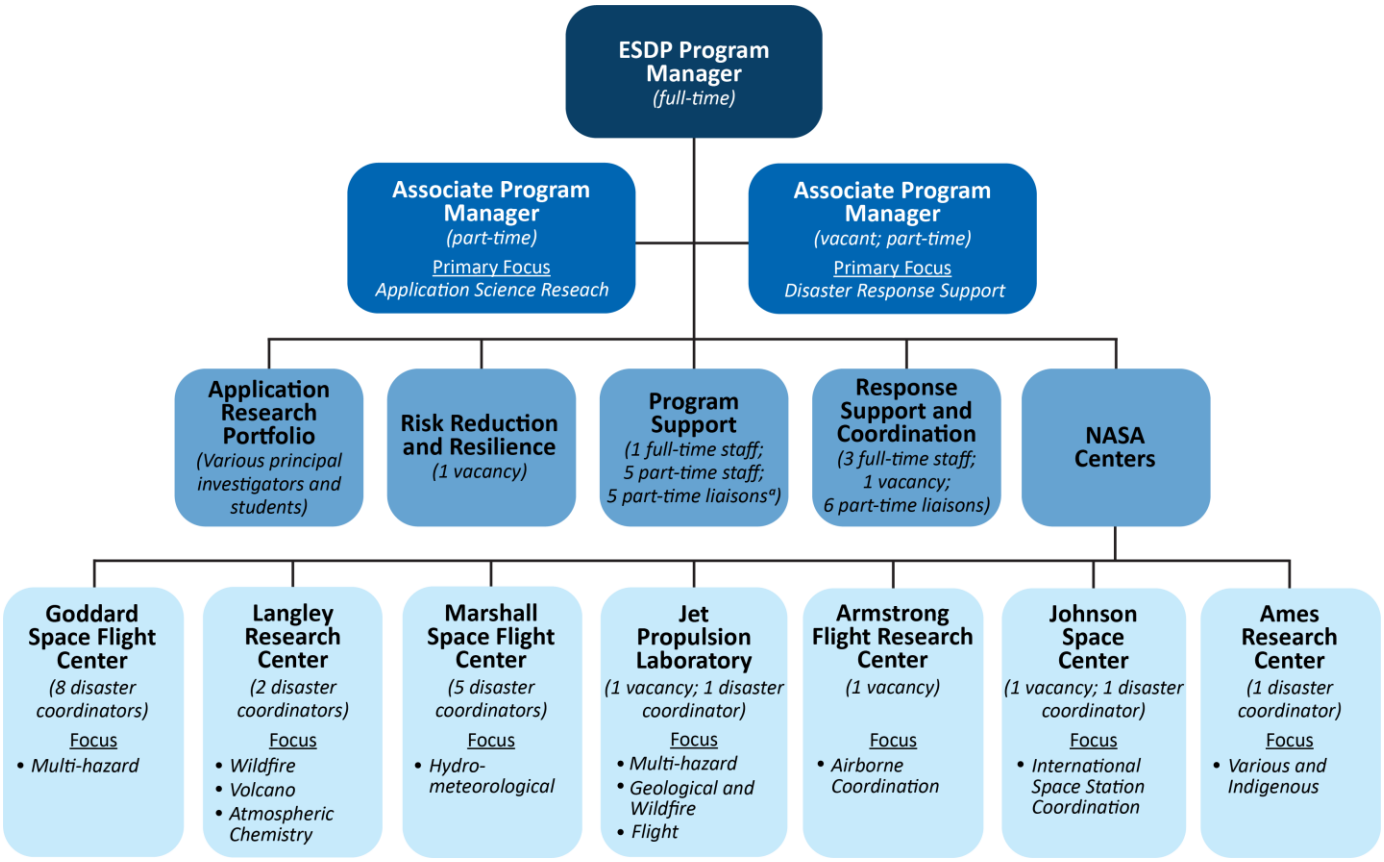
The Application Research Portfolio branch includes principal investigators and students responsible for conducting applied science research—that is, the use of scientific methods to solve practical problems, in this case to support disaster risk reduction, response, and recovery—who are sponsored through a series of grants and partnerships funded primarily by NASA Research Opportunities in Space and Earth Science (ROSES) solicitations.[6] The Risk Reduction and Resilience branch seeks to reduce risk and enhance resilience in crisis-affected communities through development of partnerships and innovative projects that bring Earth observations and humanitarian actors together to build more risk-informed human and environmental systems. The Program Support branch is primarily responsible for providing basic program administration; building and maintaining regional, interagency, and international coordination; and developing a broad range of written products.

The RSC branch provides technical, administrative, and technological support necessary for the Program to respond to disaster events. RSC includes staff responsible for the NASA Disasters Mapping Portal and other visualization technology as well as disaster response coordinators who are responsible for both remote and on-site technical and administrative coordination of rapid disaster response. Crucially, this branch is charged with determining which NASA Centers and ESDP staff will respond to an activated disaster event (occurs when ESDP staff allocate time and/or resources to engage in disaster management support).

Center response is led by disaster coordinators located at NASA Centers who support various ESDP and engagement activities including coordinating Center efforts to respond to disaster events. Centers generally focus on specific types of disasters. For example, Langley Research Center officials primarily address atmospheric chemical and volcano events, while Jet Propulsion Laboratory staff focus on geological and wildfire hazards. Figure 2 shows ESDP's organizational structure as of December 2021.

[6] NASA's Science Mission Directorate funds research and technology development primarily through the omnibus solicitation called ROSES, which is made up of different calls for proposals—each with its own topic and due date—and conducted annually using a competitive, peer review process.

Figure 2: NASA ESDP Organizational Structure (as of December 2021)

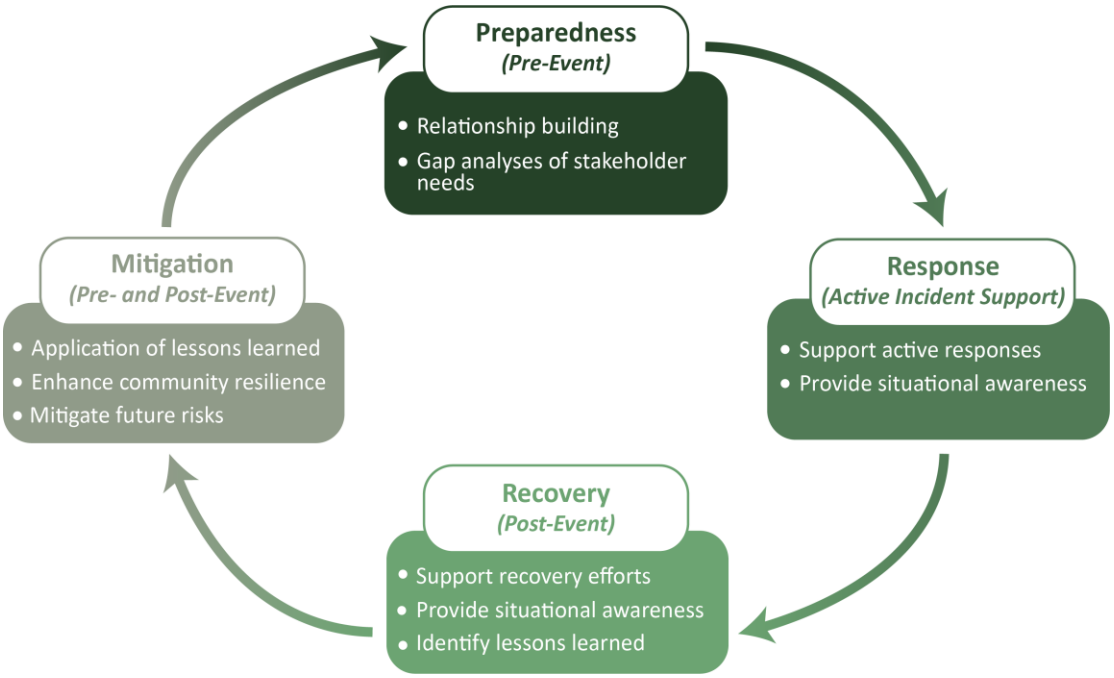


Source: NASA Office of Inspector General (OIG) presentation of Agency information.

[a] Liaison refers to individuals who are not formally a part of ESDP (and not funded through ESDP), but rather assigned to support ESDP as a part of their duties.

With a staff of 5 full-time employees and 18 part-time disaster coordinators and an annual budget of $6.5 million, ESDP sponsors the use and integration of space- and ground-based Earth observations in the decisions and actions of disaster-related organizations, including use of feasibility studies, workshops, and needs assessments. The Program is focused on disaster risk reduction and resilience across the disaster life cycle (see Figure 3) from local to global scales.

Figure 3: Disaster Life Cycle



Source: NASA OIG presentation of Agency information.

ESDP sponsors activities to improve the value and usability of NASA Earth science products in support of disaster response and recovery across a wide range of disaster types including floods, earthquakes, volcanoes, landslides, and industrial accidents. It also pursues partnerships and provides assistance to other federal agencies such as the Federal Emergency Management Agency, National Oceanic and Atmospheric Administration, Environmental Protection Agency, and United States Agency for International Development (USAID) that can carry forward NASA-developed information and tools to support the responders they serve.

For example, ESDP provided disaster assistance during the La Soufrière volcano eruption on Saint Vincent and the Grenadines. Due to signs of increased volcanic activity in the Caribbean in late 2020, USAID, through the SERVIR program, requested assistance from ESDP in January 2021 to identify and analyze Earth-observing data.[7] On April 9, 2021, the La Soufrière volcano erupted, triggering dangerous and fast-moving avalanches of hot ash and gas that forced the evacuation of over 16,000 people. ESDP established a core team and sent an assessment survey to all Center disaster coordinators to determine subject matter expertise, current related work, and partners and stakeholders involved.

2021 Eruption at La Soufrière Volcano

On April 9, 2021, the Landsat 8 satellite captured this image of volcanic ash billowing from the La Soufrière volcano on Saint Vincent Island.

Source: NASA.

[7] SERVIR is a joint development initiative between NASA and USAID that works in partnership with leading regional organizations worldwide to help developing countries use information, Earth-observing satellites, and geospatial technologies for managing climate risks and land use.

Throughout this disaster event, the Program provided data products to USAID regarding rate of change, type of change, and satellite imagery of lava flow, ashfall, and damage. NASA's efforts to monitor and assess the volcanic activity helped provide guidance and situational awareness for stakeholder decision-making.

Mapping Portal Used to Post Disaster Products

The NASA Disasters Mapping Portal (located on the Agency's Applied Sciences website at https://disasters-nasa.hub.arcgis.com/) takes disaster-related data and puts it into understandable, usable formats for use by emergency managers, interagency organizations, and the public. The goal of the portal is to bridge the gap between science products and the people who can use the data to assist in preparedness, response, mitigation, and recovery. All data in the Mapping Portal is free and openly available without any login requirements. Data can also be downloaded or imported into organizations' own Geographic Information Systems (GIS).[8] In 2021, visitors accounted for over 13,100 pageviews of the Mapping Portal.[9]

The Mapping Portal contains event-based and near-real time disaster products, dashboards, and story maps for disaster events. For example, a story map provides a description of the disaster, shows what is possible with NASA products, and highlights disaster impacts. Figure 4 shows a screen capture of a story map produced for Hurricane Ida in 2021.

[8] GIS are a collection of computer-based tools for organizing information from a variety of data sources to map and examine changes on Earth.

[9] This represents the number of homepage views and does not account for users who access direct links to other parts of the Mapping Portal.

Figure 4: NASA Story Map of Hurricane Ida (2021)

Source: NASA (January 19, 2022).

Satellites ESDP Uses for Its Disaster Products

NASA uses a variety of Earth-observing satellites as sources of information for the disaster products posted to the Mapping Portal. For example, Landsat 7 and 8 satellites are used to provide color maps for flood disasters and infrared color products for earthquakes and wildfires.[10] The Advanced Spaceborne Thermal Emission and Reflection Radiometer, onboard the Terra satellite, is an imaging instrument that is used to create detailed maps of land surface temperature, reflectance, and evaluation, and produce products like lava detection and smoke and ash plume for volcanoes.[11] In addition, International Space Station cameras are used to give an overview of an array of disaster events such as tropical cyclones and landslides. Table 1 lists the satellites that ESDP uses to produce products for disaster events.

[10] Landsat 7 and 8 were developed in collaboration with the U.S. Geological Survey and launched in April 1999 and February 2013, respectively. They continue more than 40 years of Landsat imaging and measurements of the Earth's terrestrial and polar regions.

[11] Terra was launched in December 1999 and has since observed Earth's atmosphere, ocean, land, snow and ice, and energy budget to provide unique insight into how the Earth system works and how it is changing.

Table 1: Satellites Used by ESDP (as of January 2022)

Satellite Name	Application
NASA, National Oceanic and Atmospheric Administration, and the U.S. Geological Survey	
Aqua	Water detection
CloudSat and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO)	Smoke and ash plume
ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS), *located on the International Space Station*	Lava detection
Global Precipitation Measurement (GPM)	Rainfall accumulation
Landsat 7	Feature detection
Landsat 8	Feature detection
NOAA-20	Power outage
Ozone Mapping and Profiler Suite-Limb (OMPS-L) on Joint Polar Satellite System-2 (JPSS-2), *scheduled to launch in September 2022*	Smoke and ash plume
Soil Moisture Active Passive (SMAP)	Soil moisture
Suomi National Polar-orbiting Partnership (Suomi NPP)	Power outage
Terra	Lava detection
International and Non-Commercial	
Copernicus Sentinel-1 A/B, *European Space Agency*	Flood extent
Copernicus Sentinel-2 A/B, *European Space Agency*	Water detection
Advanced Land Observing Satellite-2 (ALOS-2), *Japan Aerospace Exploration Agency*	Damage detection
PéruSAT-1, *Space Agency of Peru*	Feature detection
Commercial	
ICEYE-X2	Feature detection
Planet	Feature detection
RADARSAT-2	Flood extent and damage
Satellogic	Feature detection

Source: NASA OIG presentation of Agency data.

Note: Many of the satellites listed have multiple uses but for purposes of this report only one is presented. For a complete listing of satellite use for disaster events, visit https://maps.disasters.nasa.gov/download/documents/NASA_Disasters_Mapping_Portal_Product_Guide_20191122.pdf (last accessed March 16, 2022).

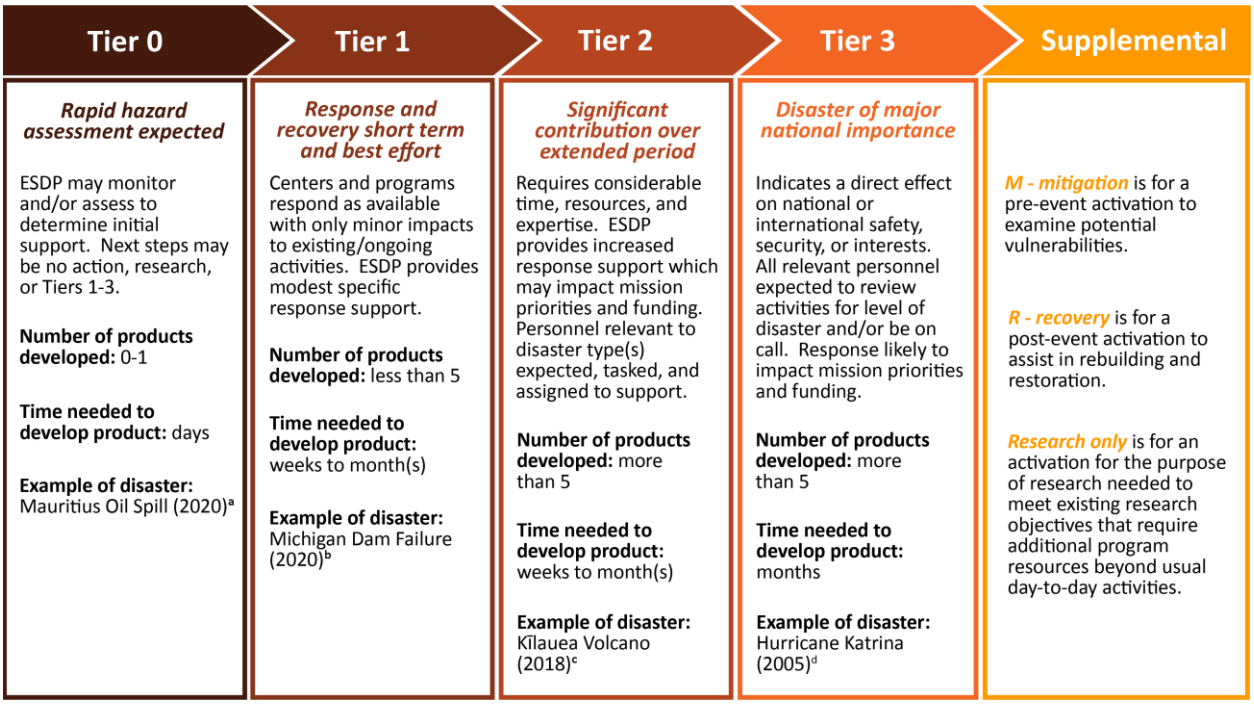
ESDP Tiered Response Framework

The NASA Disasters Program Playbook (Playbook) provides standard operating procedures and guidance for ESDP staff on expectations, roles, and tasks regarding the Agency's disaster response support. The Playbook outlines the critical multi-tiered framework ESDP uses to determine the level of disaster response support. The framework takes into account the specific disaster event and involvement of resources by leveraging two tools—the initial event screening and assessment survey. The initial event screening gathers pertinent details such as who requested support and determines if the disaster event

meets threshold criteria for ESDP's engagement. The assessment survey determines availability and applicability of resources including staff as well as potentially useful data, technology, and products.

The framework divides responses into four primary tier categories (0 thru 3), based on several factors such as the expected level of Program effort, number of and time needed to develop products, funding, and amount of time to respond (see Figure 5). For example, Tier 1 response and recovery efforts are short-term such as the Michigan Dam Failure in 2020, while Tier 3 is activated when the disaster is of major national importance such as Hurricane Katrina in 2005. In addition to these primary tiers, ESDP uses supplemental designations for some activations. The primary supplemental designations include "M," which indicates a "mitigation" or pre-event activation to examine potential vulnerabilities; "R," which indicates a "recovery" or post-event activation to assist in rebuilding and restoration; and "research only," which indicates an activation for the purpose of research needed to meet existing research objectives that require additional Program resources beyond usual day-to-day activities.

Figure 5: ESDP Tiered Response Framework (as of 2021)



Source: NASA OIG presentation of Agency information.

[a] On July 25, 2020, an oil tanker ran aground on a coral reef on the island of Mauritius. More than 1,000 metric tons of fuel leaked from the vessel into the Indian Ocean, polluting nearby coral reefs, surrounding beaches, and lagoons.

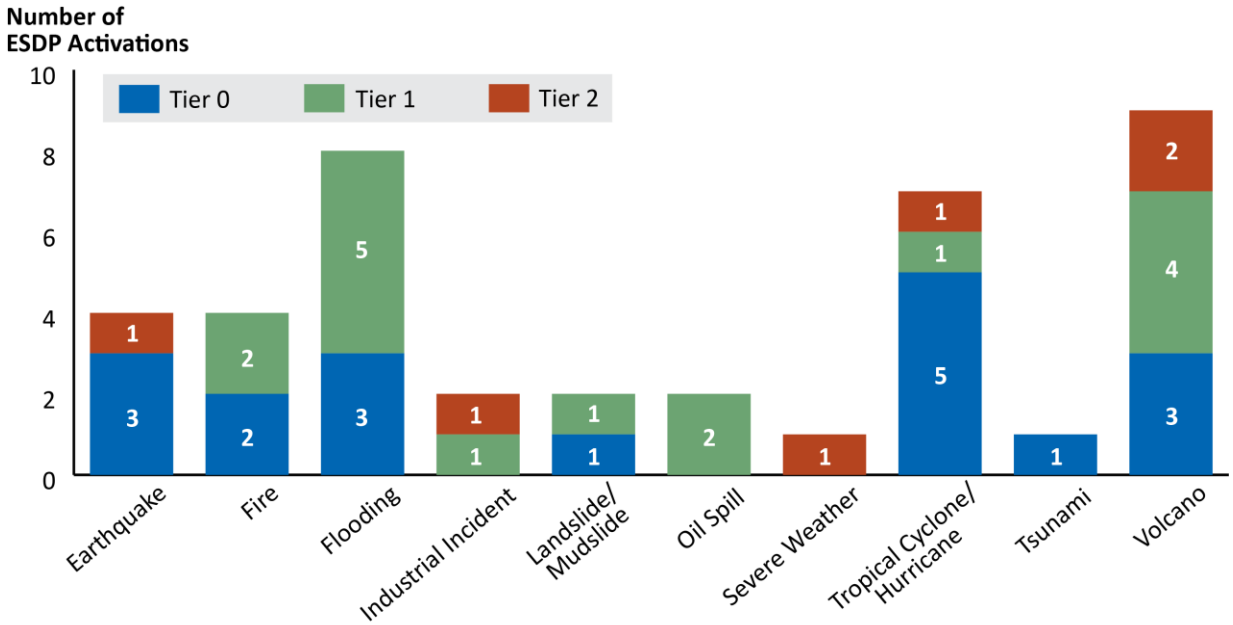
[b] On May 19, 2020, the Edenville and Sanford Dams in Michigan failed with reports of 2,500 homes, businesses, and non-profits impacted by the resulting flooding leading to at least $175 million in losses with another $34 million in damage to public property.

[c] From May through August 2018, an eruption of the Kīlauea volcano in Hawaii resulted in large lava flows and an earthquake that destroyed over 700 homes, displaced over 2,000 people, covered 30 miles of road, and added 875 acres of new land to the island. Recovery costs were reported to be approximately $800 million.

[d] From August 25 to 30, 2005, Hurricane Katrina resulted in severe storm surges, wind damage, failure of levee systems, and flooding resulting in widespread devastation along the Central Gulf Coast, with reported damages totaling over $180 billion and at least 1,833 deaths.

In 2021, the Program reported 40 disaster activations, including 18 Tier 0, 16 Tier 1, and 6 Tier 2 responses (see Appendix B for a listing of activations). The Program also breaks down the number of activations by hazard category, tier, and region of the world. For example, in 2021 ESDP activated 9 volcano and 7 hurricane events, with 3 in the Tier 2 category. ESDP divided the world into 8 regions where the Program activates disasters, and in 2021, most were from Asia (14) and North America (9). Figure 6 illustrates the Program's activations, by hazard and tier, in 2021.

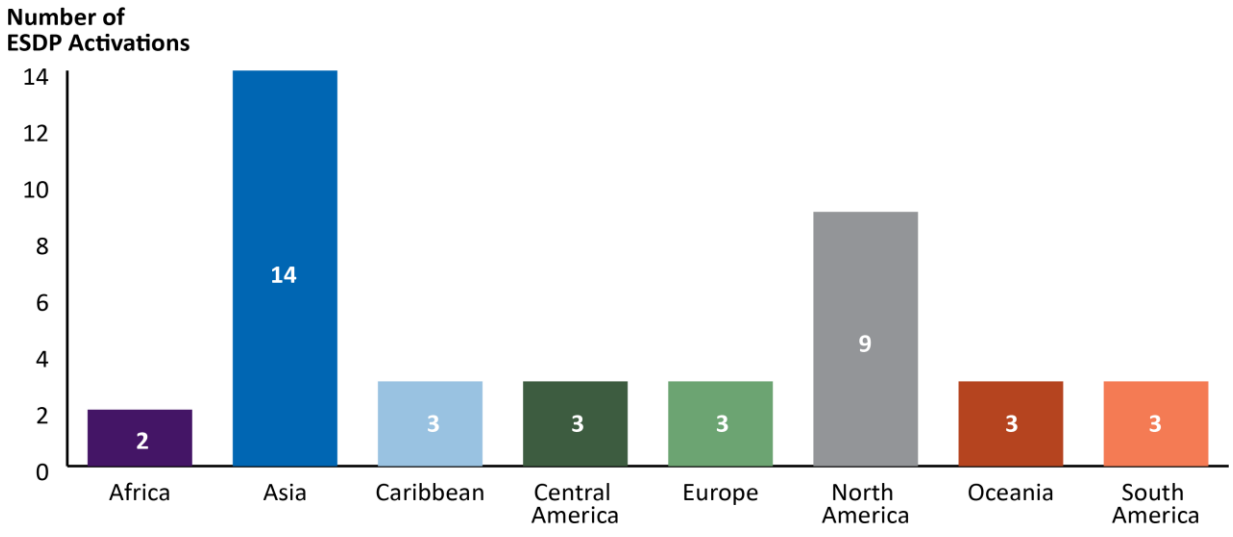
Figure 6: Number of ESDP Disaster Activations in 2021 by Hazard and Tier Designation



Source: NASA OIG presentation of Agency data.

Figure 7 shows ESDP activations, by region, in 2021 with most activations occurring in the Asia region.

Figure 7: Number of ESDP Disaster Activations in 2021 by Region



Source: NASA OIG presentation of Agency data.

ESDP Effectively Provides Data to Partners and Stakeholders but Would Benefit from Clear Program Priorities and Objectives

We found that ESDP has provided partners and stakeholders with useful and effective products to predict, prepare for, respond to, and recover from disasters; however, the Program struggles to do so efficiently because Earth Science Division (ESD) and Applied Sciences Program (ASP) leadership has not provided clear mission priorities or objectives to achieve success. ESD and ASP leadership has not created, in collaboration with the ESDP Program Manager, a strategic plan or requirements document to outline the Program's mission, goals, and objectives. Although ESD and ASP leaders have not designated ESDP as a NASA "program" in the formal sense, we believe the Program could benefit from applying Agency policy requirements that provide management guidance for all NASA research and technology programs and projects.[12] Lack of clear and consistent ESD and ASP leadership communication about ESDP's priorities has also created a disconnect regarding Program expectations, goals, and objectives. These issues, as well as the absence of a federal mandate requiring ESDP to aid in disaster response, has led to the inadequate allocation of budget and personnel resources to scale support, ensure continuity, and maintain sustainability.

ESDP Effectively Provides Unique Data to Partners and Stakeholders

ESDP collects and distributes relevant imagery, data, and damage assessments to partners and stakeholders, domestically and internationally, to support disaster risk reduction, response, and recovery. Even in light of the unpredictability of disasters, the Program utilizes its expertise and resources to effectively provide a multi-discipline systemic analysis of disasters and hazards and inform end users through all emergency management disaster life-cycle phases. ESDP also sponsors 10 ROSES projects, which cover a broad swath of hazard and disaster research, from tsunami and landslide forecasting to volcanic ash and wildfire smoke plume tracking. These research efforts aim to assemble scientifically defensible studies on disaster risk management, demonstrate the applications of NASA Earth-observing data for studying disasters, and mature the technologies and techniques developed from these projects to operational use.

[12] NASA Procedural Requirements (NPR) 7120.8A, *NASA Research and Technology Program and Project Management Requirements (Updated w/Change 2)* (September 14, 2018).

In a survey we sent to 21 ESDP partners and stakeholders, 8 of the 9 respondents said that ESDP provided responsive products in a timely manner to support their needs.[13] We also evaluated ESDP's actions during the western U.S. fires in the summer and fall of 2020 and found that the Program provided support directly to users through emails, virtual meetings, and data products. ESDP activated coordination efforts across several states and worked closely with local, state, regional, and federal entities to understand the impacts of the fires and potential risks to people, infrastructure, and the environment. The Program provided support to partners and stakeholders in California, Washington, Colorado, and Oregon, as well as to regional and federal agencies, including the United States Postal Service, United States Forest Service, United States Army Corps of Engineers, and the Federal Emergency Management Agency. In addition, ESDP provided over 20 data products to its partners and stakeholders, including satellite imagery and soil moisture, plume, and aerosol data. The map of California represents one of those products, which ESDP developed to show the state's daily average aerosol optical depth (the measure of aerosols—e.g., urban haze, smoke particles, desert dust, sea salt—distributed within a column of air from the Earth's surface to the top of the atmosphere), which helps display air quality concerns.

ESDP Air Quality Map of California

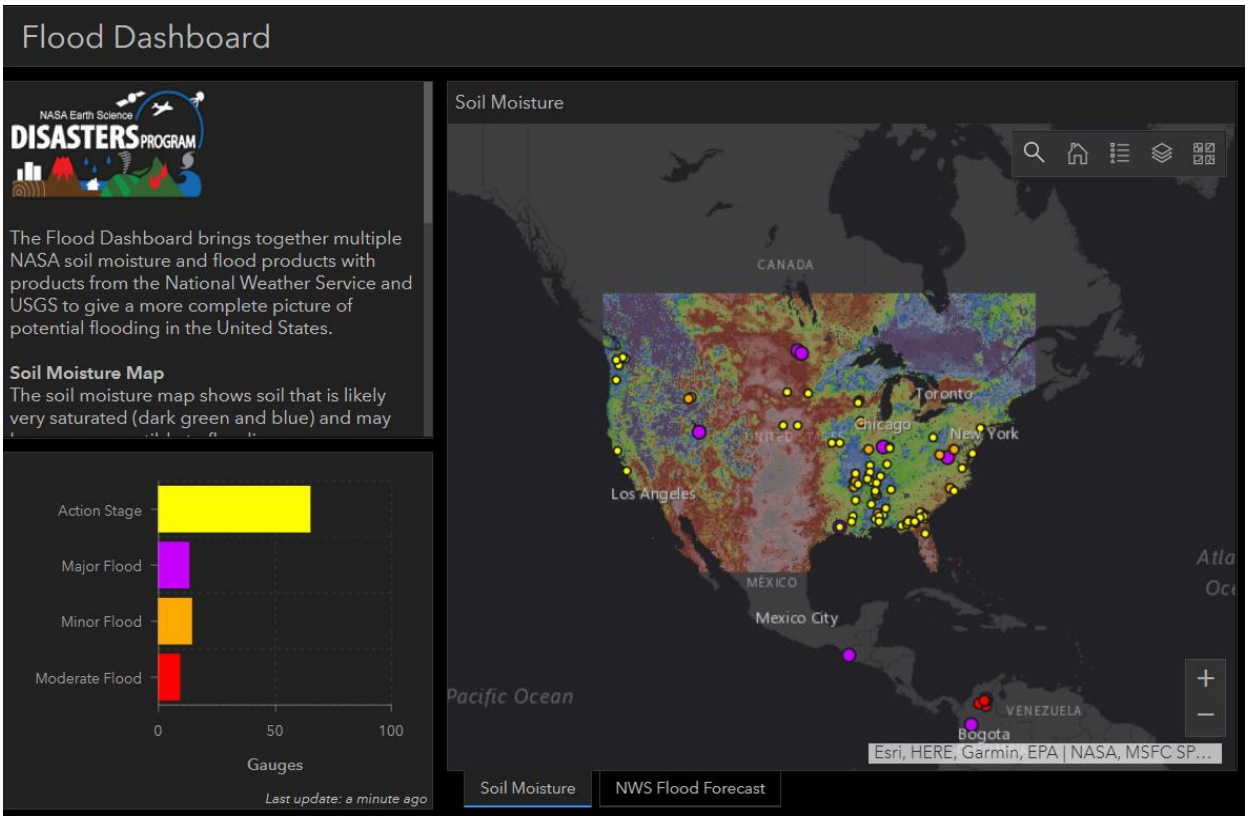
This Mapping Portal product shows the daily average aerosol optical depth over California during the fires of 2020. An aerosol optical depth greater than 0.5 indicates hazy atmospheric conditions; on this day the darkest coloration in northern California represents an average of at least 1.5.

Source: NASA.

ESDP also posts updated Earth-observing datasets on the NASA Disasters Mapping Portal, which provides NASA, its partners, and other stakeholders data in a standardized GIS format that is easy to integrate into their existing technology workflows and interpret for decision-making. In addition, the Program posts Disaster Dashboards, which provide data dashboards of different hazard types, near real-time products, and metrics on activation responses. Figure 8 shows ESDP's Flood Dashboard, which integrates data from NASA, the National Weather Service, and the U.S. Geological Survey.

[13] We sent a survey questionnaire to 21 partners and stakeholders who used ESDP products and received responses from 9, a 43 percent response rate. Our selection criteria involved conducting a judgement sample that focused on partners and stakeholders from 2019 to 2021, and included representation from international, federal, state, and local entities, as well as Tier 0 to Tier 2 disaster events. Although not generalizable to all partners and stakeholders who ESDP has worked with, the results provide perspectives of the usefulness of ESDP products.

Figure 8: Flood Dashboard of North America (2021)



Source: NASA (January 21, 2022).

In 2021, ESDP began producing a quarterly newsletter to promote its data products for partners and stakeholders on the Program's website. The newsletter highlights recent disasters the Program has been supporting, provides information on trainings, and features staff profiles and their roles in the Program. As of January 2022, almost 1,500 individuals subscribed to the newsletter, including representatives from federal, state, and local government agencies as well as educational institutions. ESDP staff told us they intend to ask the Program Manager to collect subscriber feedback on the newsletter regarding user experience and content beginning in April 2022.

ESDP Lacks Program Requirements Document to Identify Goals and Objectives

While ESDP has effectively provided data products to its partners and stakeholders, the Program has not developed a charter or finalized a program management requirements document to outline its overall goals and objectives. According to NASA Policy Directive (NPD) 1000, *NASA's Governance and Strategic Management Handbook*, Agency programs should develop a foundational document that ensures conformance to applicable institutional and programmatic requirements. Specifically, Section 3.3 of NPD 1000 states:

> Programmatic Authorities include the Mission Directorates and their respective program and project managers, where a program is defined as a strategic investment that has a defined architecture, and/or technical approach, requirements, funding level, and a management structure that initiates and directs one or more projects. Similarly, a project is a specific investment identified in a Program Plan having defined requirements, a life-cycle cost, a beginning, and an end. A project also has a management structure and may have interfaces to other projects, agencies, and international partners. A project yields new or revised products and services that directly address NASA's strategic needs.[14]

Further, NASA Procedural Requirements (NPR) 7120.8A, *NASA Research and Technology Program and Project Management Requirements*, applies to research and technology development—the creation and development of tools—that are then transferred to other NASA programs, stakeholders, and industry partners for use.[15]

According to the ASP Director and a former Earth Science Deputy Division Director, NPR 7120.8A does not apply to ESDP. They noted that ESDP is called a "program" in name only (like many other "programs" within ASP) but is not actually a NASA program in the formal sense because ESDP does not follow program requirements such as NPR 7120.8A. However, other NASA mission directorates with similarly developed programs and projects are required to follow these program requirements in accordance with NASA guidance. We believe that ESDP would benefit from following the framework outlined in NPR 7120.8A. For example, nearly the entire Aeronautics Research Mission Directorate's portfolio consists of research and technology development efforts—programs and projects—that are managed via NPR 7120.8A and are similarly advanced or matured to be transferred to stakeholders. Specifically, to address aviation industry goals of reducing fuel use, emissions, and passenger delays, NASA's Airspace Technology Demonstration portfolio partnered, created, tested, and transferred technologies to the Federal Aviation Administration and industry for use at airports across the nation.

Although in 2018 ESDP developed the NASA Disasters Multi-Year Strategic Plan (2018-2022)—hereafter referred to as the Strategic Plan—for fiscal years (FY) 2018 to 2022, according to documentation ESDP staff provided, it was not finalized due to staffing limitations, lack of feedback from ESD leadership, and lack of prioritization within the Program. In addition, based on interviews with ESD and ASP leadership and ESDP management and Program officials, work has not started on the FYs 2022 to 2026 strategic plan due to continued lack of resources and ESD, ASP, and ESDP leadership prioritization. In our view, ESDP would benefit from establishing formal program management requirements and finalizing the Strategic Plan to document ESDP priorities, expectations, and quantifiable outcome measures, as well as enhance the Agency's ability to support federal disaster response efforts under the Stafford Act.

NASA Leadership Has Not Provided ESDP Clear Direction or Expectations

Despite ESDP's growth and success, ESD and ASP leadership has not provided clear direction or expectations, creating disconnects regarding Program focus areas, criteria of a successful program, and frequency of engagement with leadership. The ESDP Program Manager was hired in 2014 and tasked to develop the Earth science disaster response and support function. Prior to the Program Manager's hiring, ASP responded in an ad-hoc manner to disaster events, with no consistency in approach or

[14] NPD 1000.C, *NASA Governance and Strategic Management Handbook* (January 29, 2020).

[15] NPR 7120.8A.

methodology. Despite the challenges associated with a lack of clear direction or expectations, the Program responded to 40 disaster events in 2021.

We sent a survey to 18 current Center disaster coordinators, who also shared it with 2 recent former Center disaster coordinators. When asked if there was a disconnect between ASP and ESDP management regarding communication, Program goals, or Program expectations, 9 of the 17 Center disaster coordinator survey respondents said yes. Specifically, they noted issues such as whether the Program's focus should be international versus domestic, what level of effort should go into a disaster response, as well as how ASP management expects the Program to engage with the community. Several ESDP staff also commented there has been inconsistent direction from ESDP management regarding the types of disasters to which the Program should respond. For example, there was confusion as to whether ESDP would continue responding to wildfire events. Center disaster coordinators were under the impression from ASP management that they were not to respond to wildfire events; however, when they received stakeholder requests to support such wildfires, ESDP management instructed them to respond.[16]

ESDP officials said that ASP management does not adequately communicate with ESDP and therefore fails to understand the Program's goals and needs. Furthermore, we found a disconnect between what ASP and ESDP management consider a successful program. While ASP management has put an emphasis on quantitative metrics, such as number of activated disaster responses or products produced, ESDP management has focused more on developing partnerships with stakeholders and building internal knowledge to add value in the future, neither of which has been formalized in the Strategic Plan.

According to ESDP officials, this disconnect is partially due to poor coordination and communication from ESD and ASP leadership. We found a low level of ESD and ASP leadership engagement, including lack of attendance at weekly coordinator meetings during which ESDP discusses a range of Program activities including responses, challenges, web postings, and updates of Program goals including partnership building. In speaking with ESD and ASP leadership, they noted it is rare for them to attend regular standing Program meetings unless specifically requested. Given that disaster response is time sensitive, complex, and includes many stakeholders, regular ESDP engagement with ESD and ASP leadership would assist the Program with more timely priority setting and decision-making. Ultimately, a lack of clear direction and objectives for ESDP has made it difficult to assess Program performance.

ESDP Faces Limitations that Hinder Its Effectiveness

ESDP has no federal mandate requiring disaster response and acts as a "best-effort" program—meaning NASA has not set minimum level program requirements. Despite NASA's status as primarily a research and development agency, ESDP officials have said the Program is sometimes treated as an operational activity where providing disaster support to partners and stakeholders becomes a priority, regardless of time or day.[17] Other agencies have also come to rely on ESDP to provide data products to assist in responding to disaster events. While the Stafford Act requires NASA to assist the federal government in its preparedness for responding to disasters, NASA is not reimbursed for its response work unlike other

[16] In late 2021, ASP leadership informed ESDP personnel that the former Wildfires program would be reestablished within ASP.

[17] In this report, a research and development agency refers to an agency funded by Congress to advance the science, technology, or methodologies to support the missions of operational agencies. An operational agency refers to an agency mandated by law to provide a service.

federal agencies that are reimbursed through the Act. Thus, the Program is sometimes challenged in terms of resources and infrastructure to efficiently carry out its mission.

An ESDP official said the Federal Emergency Management Agency requested NASA support during Hurricane Florence in 2018, assistance that involved flying an airborne asset over affected areas to collect data and create relevant products. According to the Program Manager, staff had discussions with the Office of General Counsel and Office of the Chief Financial Officer on whether authority exists under the Stafford Act for these types of reimbursable agreements and, if so, how to create a mechanism for reimbursement. Based on internal and external communications, the Program Manager and staff determined that they could create a Memorandum of Understanding with other agencies to establish the overarching agreements. However, progress stalled after the Program provided a draft Memorandum of Understanding to counterparts at the Federal Emergency Management Agency even with follow-up conversations over several months. Due to the lack of consistent Headquarters' involvement, this matter was left unresolved. As a result, the Agency supported these Hurricane Florence-related costs (an estimated $350,000), thereby limiting future response capabilities.

There are also times where ESDP must respond to requests that are not within the scope of its activation process. Despite the Program maintaining a Playbook that outlines a tiered framework for disaster activation, Congress, the Administrator and other senior NASA officials, and Science Mission Directorate leadership will occasionally inquire about high-profile disasters that ESDP had not previously activated, triggering ad-hoc work. The need to reprioritize efforts to address these requests, which average about one per month, adds to the already limited bandwidth of Program staff.

Another limitation results from a lack of adequately evaluating and allocating resource needs (i.e., budget and personnel). For example, the Program's current budget of $6.5 million has remained relatively flat for the past 5 years. ESDP consists of 5 full-time employees and 18 part-time disaster coordinators who dedicate approximately 5 to 75 percent of their time to ESDP activities. According to a proposed FY 2022 staffing plan sent to ASP leadership, the Program typically experiences staff turnover of around 25 percent each year. The proposed staffing plan noted that there are currently no disaster coordination manager or GIS/Earth data systems administrator backups available, and full-time employee performance plans and contracts do not adequately provide flexibility for coverage of scheduled or emergency leave or for surge capacity when multiple disaster events occur and escalate. As a result, the Program is short-staffed and, according to multiple ESDP officials, personnel are experiencing burn out. While the nature and frequency of disasters is understandably unpredictable, ESDP currently does not have an adequate level of budget or staffing to scale support, ensure continuity, and maintain sustainability in its response activities.

ESDP Guidance for Providing Disaster Support Incomplete and Inconsistently Used

Guidance for providing support to entities addressing disaster events is incomplete and inconsistently used by ESDP staff. ESDP relies on the Playbook, which provides standard operating procedures and guidance on expectations, responsibilities, and tasks regarding disaster response support activities. Established as a Program requirement in the draft FYs 2018 to 2022 Strategic Plan, the Playbook is crucial to the day-to-day activities of ESDP. Yet both the Strategic Plan and Playbook remain in draft and the Playbook is inconsistently followed, according to staff, largely due to lack of time, resources, prioritization, and training. Additionally, we found a low level of awareness of the existence of the Playbook among some Center disaster coordinators. As a result, this has created communication, prioritization, and workflow inefficiencies between ESDP employees at all levels as well as with ESD and ASP leadership.

NASA Disasters Program Playbook Is Incomplete

In 2016 and 2018, ESDP developed two Program documents—the Playbook and the Strategic Plan for FYs 2018 to 2022, respectively—to guide and support its mission and activities. Along with four strategic goals, the Strategic Plan established the requirement for development of a Playbook. Given the lack of charter, Program requirements document, or federal mandate, the Playbook—intended for use primarily by ESDP management, Program officials, and staff—serves as the sole guidance that details the procedures for ESDP to provide disaster response support throughout the disaster cycle as well as to respond to requests for data and opportunities to advance research. However, as of January 2022 both the Strategic Plan and Playbook are labeled as "draft." While in draft, both documents are used and presented as operational guidance. According to interviews with ESD and ASP leadership and ESDP management, work has not started on the FYs 2022 to 2026 strategic plan nor on updates to the Playbook.

According to one Center disaster coordinator, the Playbook was intended to be a "living document," meaning as the Program learned, edits and updates would be made routinely to the Playbook. Further, the Playbook includes requirements for an annual review for potential revisions, modifications as necessary due to programmatic changes, and updates to points of contact at least biannually. However, these routine updates happen infrequently and as a result, the Playbook requires extensive updates that entail significant time and resources.

Since 2016, ESDP has overhauled the Playbook several times, most recently in 2019 although it is still labeled as a draft document. According to the Program Manager, the Playbook is in draft due to a lack of review and approval by ASP leadership and the Centers' Earth Science Division directors. However, after the most recent version of the Playbook in September 2020, ASP leadership informed the Program Manager that the Playbook was in an adequate condition and requested a final copy. The draft

Playbook includes references to 14 appendixes, but 7 are currently blank with notes such as "updates in progress" or "placeholder." These missing appendixes include helpful tools such as an after-action summary template and event lead checklist. Additionally, the draft Strategic Plan requires that the Playbook include 6 hazard-specific annexes, which the draft Playbook was lacking as of December 2021. In addition, all annexes and appendixes were either incomplete or require updates (see Table 2 for a listing and status of Playbook annexes and appendixes). According to ESDP officials, the Program does not have the time, resources, and staff to complete or regularly update the Playbook due to its disaster response efforts and staff shortages and turnover.

Table 2: NASA Disasters Program Playbook Annexes and Appendixes (as of February 2022)

Annex/Appendix Name	Updates Required[a]	Incomplete[b]	Not Included[c]
Annexes			
Earthquake Annex		X	X
Flooding Annex		X	X
Wildfire Annex		X	X
Volcanic Eruption Annex		X	X
Tropical Cyclone Annex		X	X
Airborne Asset Annex	X		X
Appendixes			
Appendix A. Disasters Program Personnel	X		
Appendix B. Disasters Program Funded Research	X		
Appendix C. Coordinating Agencies and Organizations		X	
Appendix D. Activation in Support of Disaster Management	X		
Appendix E. International and Interagency Relations		X	
Appendix F. Headquarters Disaster Coordinator Checklist		X	
Appendix G. Event Lead Checklist		X	
Appendix H. GIS Team Workflow		X	
Appendix I. Workflow: Office of Communications	X		
Appendix J. Workflow: Web and Social Media	X		
Appendix K. Template: Core Team Meetings	X		
Appendix L. Template: Leadership Briefings	X		
Appendix M. Template: After-Action Summary		X	
Appendix N. Acronyms		X	

Source: NASA presentation of Agency information.

[a] Updates Required indicate the annex or appendix has been created but contains outdated information.

[b] Incomplete indicates the annex or appendix has not been created.

[c] Not Included indicates the annex or appendix is referenced as a part of the Playbook but not present in the Playbook.

NASA Disasters Program Playbook Is Not Used Consistently

While the Playbook serves an essential function even in its current draft form, awareness and use of the current draft Playbook varies significantly across Centers. In the survey sent to 18 current and 2 recent former Center disaster coordinators:

- 8 reported not using the Playbook due to various reasons including they did not know where to locate it and one of these coordinators was not aware of the Playbook's existence. According to ESDP staff, the draft Playbook has been shared several times and is available on the ESDP shared drive.
- 9 reported using the Playbook and of those, 7 rated it as at least moderately helpful and sufficient in content. However, multiple coordinators highlighted the lack of consistent implementation of the Playbook, with one noting it is not "useful" due to lack of consistent application across ESDP.

Significant confusion and conflict exists between ESDP management, officials, and Center disaster coordinators over the expected application of the Playbook in terms of whether fundamentally it is a flexible guide or a strict set of standard operating procedures. According to an ESDP official, due to the nature of disasters and the varied levels of support the Program can provide, the Playbook should be flexible and not be used as standard operating procedures; however, this official emphasized that the Centers view the Playbook more rigidly. In contrast, according to multiple Center disaster coordinators, the Centers understand the need for flexibility but emphasized that ESDP management and staff do not consistently apply critical Playbook elements when responding to or determining whether to respond to disasters such as the tier level framework, initial event screening, and assessment survey.[18] As one Center disaster coordinator observed, there is always a disaster somewhere and it is critical for the Program to have a process for determining which disasters to support as it is not feasible for the Program to respond to every disaster.

As one Center disaster coordinator observed, there is always a disaster somewhere and it is critical for the Program to have a process for determining which disasters to support as it is not feasible for the Program to respond to every disaster.

According to ESDP officials, the Program does not have the necessary time, resources, and staff to appropriately follow critical steps (e.g., the assessment survey) due to real-time disaster response and staff shortages and turnover. In addition, ESDP management does not prioritize the implementation or regular revision of the Playbook. According to multiple staff, the Program Manager routinely deviates from processes detailed in the Playbook. For example, the Playbook discusses the initial event screening, which outlines the process and criteria to determine if the Program will provide support. According to one Center disaster coordinator, the Program Manager directed the Program

[18] The tier level framework takes into account the specific disaster event and involvement of resources by leveraging two tools: the initial event screening and assessment survey. The initial event screening gathers pertinent details such as who requested support and determines if the disaster event meets the threshold criteria for ESDP's engagement. The assessment survey determines availability and applicability of resources including staff as well as potentially useful data, technology, and products.

to respond to the Australia flooding event in 2021 despite it not meeting Playbook criteria.[19] Another Center coordinator stated the Playbook "is not emphasized or promoted by Program management to coordinators."

According to an ESDP official, the training provided to Center disaster coordinators is minimal—they were last provided Playbook training in 2020 as a part of their regular coordinator calls. Training is often canceled due to staff "[getting] overwhelmed with actual incidents." One coordinator noted there is no onboarding process or communication of expectation regarding use of the Playbook. ESDP staff acknowledged the lack of training regarding the Playbook and disaster response in general and cited insufficient time, resources, and staff due to real-time disaster response and staff shortages and turnover.

Another source of deviation from the Playbook is ASP leadership influence that may trigger an activation outside of the framework, which often results in ESDP management and staff skipping critical steps from the Playbook or leadership pushing back on the tier assignment. For example, according to the Playbook ESDP determines the tier level of an event. However, during the California Wildfires in 2018, ASP leadership stalled escalating the event from a Tier 2 to a Tier 3 despite the significant analytical, coordination, and product development effort by Program staff. According to an ESDP official, the escalation was slowed due to ASP leadership's concerns about the potential funding impact and their misunderstanding of the mechanics of the Tiered Response Framework. Specifically, ASP leadership did not agree with the Program's assessment of a Tier 3 and required further documentation to demonstrate the extent of work conducted by Program staff. According to an ESDP official, escalating the incident to a Tier 3 would have accurately reflected the magnitude of the disaster event and the level of effort required. In our view, although California Wildfires met the criteria for Tier 3 and the Playbook identifies escalation of tiers as a staff responsibility, it also states that a Tier 3 activation may involve significant additional funding and reprioritization of mission operations as directed by NASA leadership, rendering ASP leadership's concerns and questions legitimate. Further, this example illustrates the negative impact of both the incomplete and inconsistently applied Playbook and the disconnect between ASP leadership and ESDP officials.

Incomplete and Inconsistently Used Guidance Hampers Disaster Response Support

ESDP employees at all levels apply the Playbook's guidelines inconsistently, if at all (8 of 17 Center disaster coordinators survey responses said they do not use it), struggle to communicate expectations and prioritize work, and are unable to update the Playbook regularly. According to Program staff, inefficiencies and frustrations are due to repeated back-and-forth conversations between Center disaster coordinators and Program officials about the Playbook and its appropriate application to disaster events. For example, prior to an activation the Playbook states that Program officials will conduct a survey assessment of the availability and capabilities of Center disaster coordinators and principal investigators. This assessment uses survey software to collect and analyze responses allowing for coordination of efforts. However, instead of following this process, activation activities regularly begin over email during non-business hours. As a result, Program officials do not send out the survey, but rather comb through dozens of emails to manually collect and create a spreadsheet containing this

[19] Persistent, heavy rain fell for several days in late March 2021 in New South Wales, Australia, leading to the region's worst flooding in six decades.

information. This most recently occurred while ESDP provided disaster support response to Malaysia Flooding in December 2021. According to Program officials, manual collection and compilation of critical information takes several hours longer than distributing, completing, and reviewing the survey and delays other tasks. In turn, these delays impact the Program's ability to provide time-critical disaster response support.

Additionally, skipping critical steps in the Playbook challenges Center disaster coordinators to prioritize and balance their work. For example, one Center disaster coordinator described a regular dynamic in which ESDP Headquarters personnel will ask what work is being done on a specific disaster. However, ESDP has not officially activated for this disaster, leaving the Center disaster coordinator feeling surprised and confused. When the Center disaster coordinator asks if an assessment has been conducted or shared, the response is "no" because there was insufficient time. The Center disaster coordinator emphasized that without such an assessment, there is a lack of important information and confusion about the stakeholder or partner as well as the availability of staff and applicable NASA capabilities. As stated in the Playbook, the results of the assessment determine if the Program will initiate further support, determine if no further action is necessary or feasible, or recommend that the Program continue monitoring the situation. In addition, due to the lack of a finalized Playbook and completed appendixes, Program officials and Center disaster coordinators are unable to use helpful tools such as checklists or templates to better manage and execute their work.

ESDP Rarely Conducts and Documents After-Action Activities for Its Disaster Responses

ESDP rarely conducts or documents integral after-action activities for disaster responses. NASA policy requires capturing and sharing knowledge to continuously improve the performance of the Agency, and ESDP's draft Strategic Plan requires capturing and integrating lessons learned and improvement opportunities.[20] In addition, the Playbook outlines how after-action assessments should be conducted.[21] However, due to the increasing rate and severity of disasters and limited staff, ESDP rarely completes such assessments. Even when documented, the Program does not effectively track after-action assessment recommendations or whether improvements are implemented for disaster responses. Ultimately, limited and incomplete after-action activities can adversely impact the efficiency of the Program, resulting in missed opportunities to improve processes and products and enhance internal communication and collaboration.

After-Action Activities Are Rarely Conducted or Documented and Recommendations Are Not Effectively Tracked

After-action activities provide essential opportunities for ESDP to review its processes and products following a disaster activation. These activities would allow ESDP to identify inefficiencies and develop improvements for future activations. This is consistent with NASA's policy to effectively manage Agency technical, program, and project management knowledge to cultivate, identify, capture, retain, utilize, and share knowledge in order to continuously improve the performance of NASA in implementing its mission.[22]

Further, the draft Strategic Plan indicates that ESDP should implement a continuous improvement or after-action program as well as follow processes outlined in the Playbook for disaster responses. The after-action process is designed to ensure that lessons learned and improvement opportunities are efficiently and effectively captured and integrated as part of the process. While the Strategic Plan does not specifically address the frequency or format for conducting these activities, the Playbook identifies after-action activities as an integral part of the activation workflow (see Figure 9) and provides additional detail on how the after-action activities should be conducted. Specifically, it notes the Event

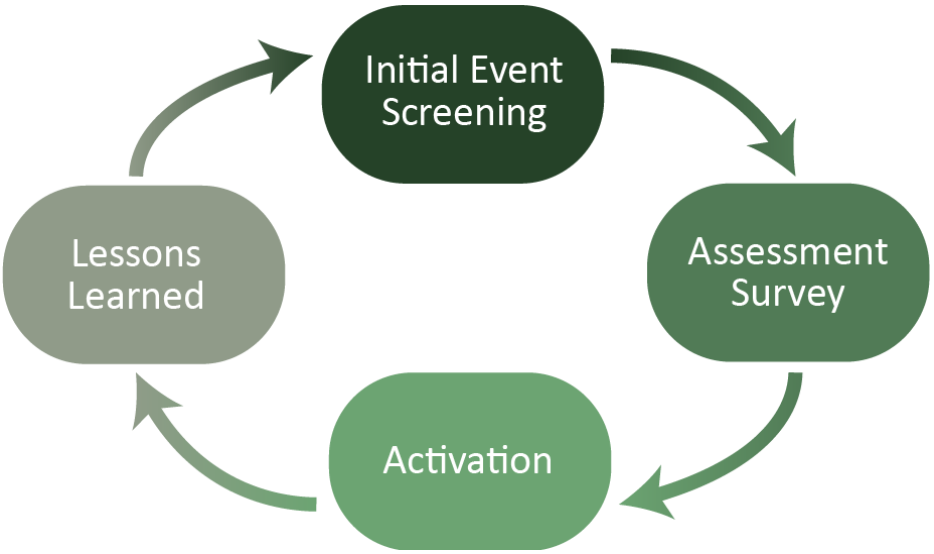
[20] NPD 7120.6A, *Knowledge Policy for Programs and Projects* (December 16, 2019).

[21] In our report, an after-action assessment refers to a formal documented report on a number of activities the Agency may label as lessons learned, after-action report, after-action study, hot wash, or improvement plan.

[22] NPD 7120.6A.

Lead and Headquarters disaster coordinator(s) should consolidate lessons learned into a summary and/or presentation slides, as appropriate, for inclusion in quarterly and yearly reports.

Figure 9: High-Level Workflow of Activation Coordination



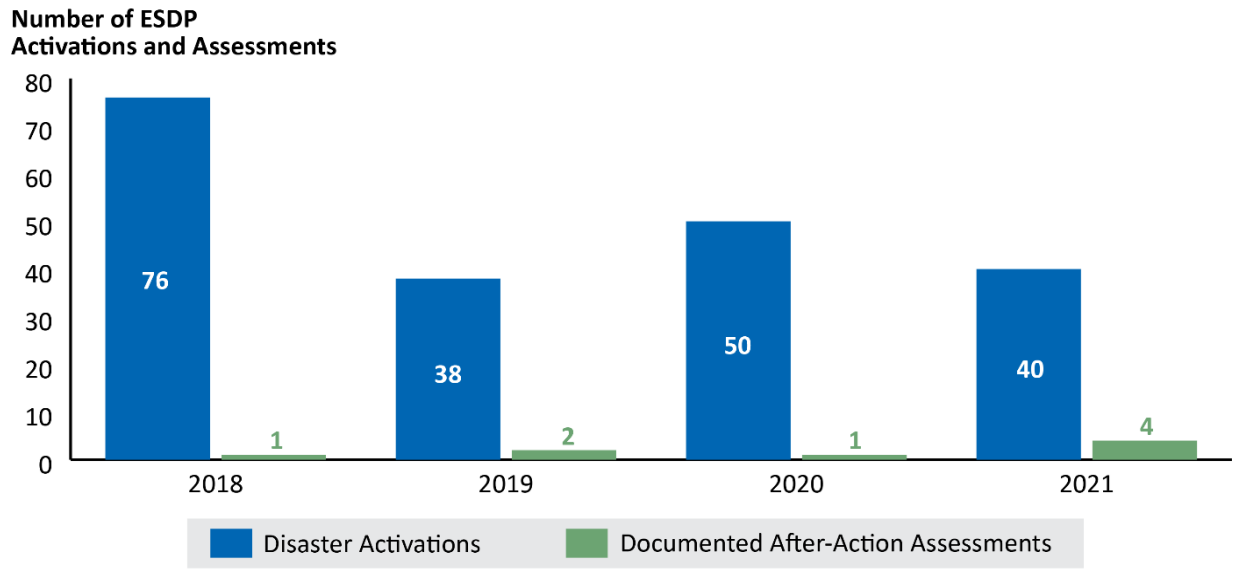
Source: NASA OIG presentation of information from the NASA Disasters Program Playbook.

Conducting and Documenting After-Action Activities

According to an ESDP official, the Program is significantly deficient in collecting meaningful lessons learned and emphasized the Program's struggles to conduct and document after-action assessments for its disaster activations each year. From 2018 through 2021, ESDP provided assistance for 204 disasters; however, Program officials were only able to provide us 8 documented after-action assessments (see Figure 10).[23] While every activation may not require an after-action assessment, in our view the low volume of lessons learned conducted between 2018 and 2021 is insufficient to gather meaningful data for future improvement.

[23] Although the scope of our audit covers ESDP's work ending in December 2021, two of the after-action assessments provided cover activations that began in 2021 and continued into 2022.

Figure 10: Number of ESDP Disaster Activations and Documented After-Action Assessments (2018-2021)

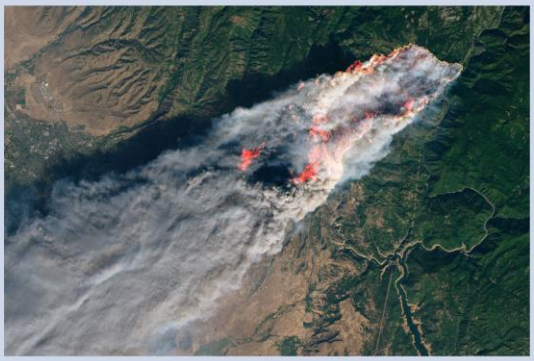


Source: NASA OIG presentation of Agency data.

Moreover, we found the few ESDP after-action assessments completed lack consistency, varying significantly in format, detail, and length.[24] Formats used to document these assessments include spreadsheets, PowerPoint slides, Word documents, and PDF reports and range from a few lines to 22 pages. For example, while the lessons learned spreadsheet for the 2021 La Soufrière volcano activation identifies two areas for improvement, there are several incomplete components such as identifying due dates and responsible parties for addressing recommendations. According to the Program Manager, the main process for conducting after-action activities is "a few phone calls…have a few dialogs and take a few notes…but nothing [is] really documented." In comparison, the after-action report for the 2018 California Wildfires provides an overview of the disaster, identifies successes and lessons learned, and develops recommendations to address areas for improvement. However, the after-action assessment is dated April 2019 and remains in draft as of February 2022.

According to the Program Manager, the process for completing detailed after-action assessments can be extensive and time consuming and can result in assessments that we found the staff do not read or, in many cases, do not have access to. One Center disaster coordinator noted that completed assessments are "not shared/promoted through the

2018 California Wildfires



On November 8, 2018, the Landsat 8 satellite captured this image of the Camp Fire, which erupted that day 90 miles north of Sacramento, California.

Source: NASA.

[24] While the Playbook allows for flexibility for after-action assessments, it outlines expectations such as: identify and discuss opportunities for improvement, solicit feedback, create a summary of events and opportunities for improvement, and add recommendations to an improvement plan.

whole team." Another Center disaster coordinator observed that after-action activities become "a grand event involving both those that participated in the event and those that didn't." ESDP staff concurred with that assessment, noting the 2018 California Wildfires after-action assessment began as a 10-page report, swelled to 80 pages, then was cut back down to 22 pages.

In a survey sent to 18 current and 2 recent former Center disaster coordinators, 9 of the 17 responses expressed concerns about the impact of limited after-action activities.[25] Center disaster coordinators reported participating in a range of after-action activities from ad-hoc feedback sessions to developing detailed reports but emphasized the rarity of these activities. In their responses, they highlighted the need for standardization for conducting after-action activities and implementing recommendations as well as a lack of dissemination and implementation of assessment report recommendations. As one Center disaster coordinator observed, without these assessments, the Program is "missing one way to encapsulate all feedback and review to see if it's worth changing processes or make improvements." Another Center disaster coordinator noted that without after-action activities, the Program's "best feedback" is provided when partners call them for support when another disaster strikes, indicating that the Program's input is valued. While return end users may demonstrate the usefulness of ESDP disaster response, without regular after-action activities the Program is limited in its ability to improve internal work processes and products to provide disaster response support more efficiently.

ESDP officials emphasized they do not have the time or resources to consistently conduct and document after-action activities. Once they have completed work on one disaster, they generally must immediately assist with another. They stated it is challenging to set aside the necessary time and maintain interest and focus with other disasters actively occurring, especially as after-action assessments can snowball into goliath endeavors. Similarly, ESDP's attempts to gather feedback from end users has been challenging due to limited responses as partners and stakeholders shift focus to the next disaster or recovery activities. In addition, ESDP officials described a lack of prioritization by ASP and ESDP leadership as a barrier to conducting and documenting after-action activities and implementing Program improvements.

ESDP Does Not Track After-Action Activity Recommendations Effectively

While the after-action assessments demonstrated ESDP's ability to identify shortcomings and areas for improvement as well as develop recommendations to address these issues, the Program does not track after-action assessment recommendations or whether improvements are made. ESDP officials acknowledged recommendations should be tracked through a process improvement plan, but this does not occur in an effective, streamlined manner due to lack of time and resources as well as shifting priorities of another active disaster or leadership request. Although the Program previously developed a process improvement plan to track recommendations, the plan is outdated and incomplete as it only includes recommendations for activations from May 2018 to March 2019. In addition, approximately 80 percent of activity statuses are listed as "not started" or "ongoing" with no additional detail.

The lack of after-action activities and implementation of improvements is widely acknowledged by Program management and staff. According to ESDP officials, recommendations are discussed occasionally on an ad-hoc basis during weekly meetings. However, ESDP officials and multiple Center

[25] We sent the survey to 18 current Center disaster coordinators and it was shared with 2 additional recent former Center disaster coordinators. Out of the 20 Center disaster coordinators, 17 responded.

disaster coordinators noted that recommendations are not implemented. As one coordinator stated, "post-deactivation work has good intentions, but it rarely brings about change in how we respond to events in the future." As with conducting and documenting after-action assessments, ESDP officials cited a lack of time, resources, and prioritization by ASP and ESDP leadership to track recommendations.

Limited and Incomplete After-Action Activities Impede Program Efficiency

Limited and incomplete after-action activities impact the efficiency of the Program resulting in duplicity of efforts, forestalling potential improvements to processes and products, and contributing to poor internal communication and collaboration. ESDP employees at all levels emphasized the importance of after-action activities and the adverse impact of not adequately completing these activities. For example, as the Program Manager described, "for many of the hurricane events…we had to reinvent the wheel and reproduce information such as flood or fire damage products previously used because we have not had the time to make product and operational improvements."

> ***As the ESDP Program Manager described, for many of the hurricane events...we had to reinvent the wheel and reproduce information... previously used because we have not had the time to make product and operational improvements.***

In one after-action assessment ESDP provided, the Program stated they did not meet end-user needs and there was duplicity of efforts. For example, ESDP produced flood proxy maps using satellite data, which ultimately did not meet end-user criteria because the maps did not capture reported damage and needed validation. However, the Program provided additional data through aviation radar mapping that end users were able to use to help make decisions. They also noted that using NASA GIS data would have been helpful, but that their GIS staff was already overworked. Additionally, the assessments concluded that ESDP needs to improve partners' and stakeholders' awareness of the Program and its capabilities, provide more training for partners and stakeholders, and address concerns regarding false readings and spatial and temporal resolution of the products.[26] However, applicable lessons learned or recommendations are rarely implemented by ESDP. One Center disaster coordinator observed about the lack of follow through that "it feels as though time and effort of those putting together the [after-action assessment] documents is wasted."

In summary, ESDP is moving from disaster to disaster without the time and resources to conduct follow-up work with partners and stakeholders to learn how to make product and operational improvements, fully understand the true impact of its work, or determine ways to broaden partnerships with the disaster community.

[26] In ESDP's assessment, false readings refer to events when end users identified false negative and false positive readings when comparing the ESDP product to ground-truth data. Spatial and temporal resolution refers to feedback received by end users indicating concerns regarding the spatial resolution being too coarse, as well as the need for rapidly updated products.

CONCLUSION

Disasters ranging from tropical cyclones to droughts to wildfires are becoming more frequent and intense around the world, causing billions of dollars in damage annually. NASA's ESDP uses Earth-observing data and applied science research to provide domestic and international partners and stakeholders with products, information, and observations to improve the prediction of, preparation for, response to, and recovery from hazards and disasters around the world.

Although ESDP effectively collects and distributes unique imagery, data, and other disaster-related products and information to these partners and stakeholders, ESD and ASP leadership has not provided the Program with clear mission priorities or objectives. With no charter, Program requirements document, or federal mandate, the Program has experienced shifting priorities and inconsistent ESD and ASP leadership messaging on ESDP's focus. In addition, Program guidance for providing disaster support is incomplete and inconsistently followed by ESDP. For example, almost 50 percent of the Center disaster coordinators that responded to our survey indicated they do not use the Playbook. Finally, ESDP rarely conducts and documents after-action activities for its disaster responses.

While the frequency and severity of disasters are understandably unpredictable, ESDP does not have adequate resources to scale support, ensure continuity, and maintain sustainability in its response efforts. The Program can address these challenges and better position itself to assist partners and stakeholders combating disaster events by establishing Program management requirements that clearly explain priorities and objectives, completing guidance for responding to disasters, and conducting and documenting more frequent after-action activities to effectively identify disaster response improvements and enhance the products it provides to entities in the United States and abroad.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To improve NASA's management of the Earth Science Disasters Program, we recommended NASA's Associate Administrator for Science Mission Directorate direct the Earth Science Division Director to:

1. Establish and document Program management requirements in a strategic plan and/or NPR 7120.8A project plan format for consistent messaging on ESDP priorities, objectives, and quantifiable performance metrics.
2. Perform a funding analysis of ESDP to determine if current resources are adequate to manage, oversee, and administer Program goals and objectives in accordance with its strategic plan and/or project plan.
3. In accordance with the Stafford Act, coordinate with appropriate NASA offices to develop Memorandums of Understanding that facilitate reimbursement agreements with applicable federal agencies that request Agency support for disaster events.
4. Require ESDP, in coordination with ASP leadership, to finalize the NASA Disasters Program Playbook and complete associated annexes and appendixes.
5. Ensure ESDP provides regular training to Center disaster coordinators regarding the Playbook and expectations of application.
6. Require the ESDP Program Manager to develop a formalized plan to capture knowledge and increase the frequency of conducting after-action activities as appropriate.
7. Require the ESDP Program Manager to develop a system to track lessons learned recommendations resulting from after-action assessments to ensure the recommendations are implemented and routinely evaluated for effectiveness.

We provided a draft of this report to NASA management who concurred with our recommendations and described planned actions to address them. We consider the proposed actions responsive and will close the recommendations upon completion and verification.

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 Raymond Tolomeo, Science and Aeronautics Research Audits Director; Adrian Dupree, Project Manager; Sarah Hughes; David Lu; and Lauren Suls.

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.

PAUL MARTIN

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Paul K. Martin
Inspector General

APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from June 2021 through May 2022 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 ESDP. We evaluated whether the Agency can effectively (1) provide data and information products to entities to predict, prepare for, respond to, and recover from disasters and (2) evaluate the output and outcomes of its efforts to assist entities with disasters.

To determine if NASA effectively provides data and information products to entities that combat disasters, we conducted interviews with ESDP officials to gain an overall understanding of Program operations to identify any documented Program goals, objectives, and expectations. We also held interviews to identify products they provide for disaster events and if there were any inherent limitations that could hinder ESDP's effectiveness with providing disaster information. We reviewed the NASA Disasters Mapping Portal website to identify and review the type of disaster products they produce in their efforts to assist their partners and stakeholders with disaster events. We also reviewed and analyzed Disaster Program Annual Summary reports to identify which disaster events ESDP officials provided assistance and the NASA Disasters Mapping Portal Product Guide to identify satellites they used to produce disaster products.

To evaluate NASA's output and outcome efforts with assisting entities with disasters, we interviewed ESDP officials to gain an understanding of the process used for activating disaster assistance, evaluating the impact of disaster products and information provided, and conducting after-action assessments. We reviewed and analyzed the draft NASA Disasters Multi-Year Strategic Plan (2018-2022) and the NASA Disasters Program Playbook to identify guidance provided to ESDP officials for conducting disaster responses. We also reviewed after-action documents to identify what performance and process improvements ESDP officials identified for activated disaster events.

We developed two survey questionnaires with the intent of gathering individual perspectives on specific aspects of the Program, as opposed to making statistical projections. We conducted a 21-question survey that was sent to 18 current Center disaster coordinators that was shared with 2 recent former Center disaster coordinators (17 replied) to gather information on their roles and responsibilities, expectations set by management, use of the Playbook, and after-action work. We had follow-up interviews with four Center disaster coordinators for additional information based on their survey responses. In addition, we conducted a 12-question survey that was sent to 21 ESDP partners and stakeholders (9 replied) to gather information on the data products the Program provides, the timeliness of these data products, stakeholder use of the Mapping Portal, and ways to improve the Program. Our selection criteria involved conducting a judgement sample that focused on partners and stakeholders from 2019 to 2021 and included representation from international, federal, state, and local entities, as well as Tier 0 to Tier 2 disaster events.

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

- Robert T. Stafford Act Disaster Relief and Emergency Assistance Act, Pub. L. No. 93-288, as amended, 42 U.S.C. 5121 et seq.
- Consolidated Appropriations Act, 2021, Pub. L. No. 116-120 (2020)
- NPD 7120.4E, *NASA Engineering and Program/Project Management Policy* (June 26, 2017)
- NPD 7120.6A*, Knowledge Policy for Programs and Projects* (December 16, 2019)
- NPD 1000.0C, *NASA Governance and Strategic Management Handbook* (January 29, 2020)
- NPR 7120.8A, *NASA Research and Technology Program and Project Management Requirements (Updated w/Change 2)* (September 14, 2018)
- NPR 7120.5F, *NASA Space Flight Program and Project Management Requirements* (August 3, 2021)
- NPR 2200.2E, *Requirements for Documentation, Approval and Dissemination of Scientific and Technical Information* (December 17, 2021)

Assessment of Data Reliability

We used limited computer-processed data that was submitted by NASA officials to evaluate the Agency's management of ESDP. 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 ESDP relative to effectively providing disaster products and information to entities and evaluating the output and outcome of NASA's efforts to assist entities with disasters. 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 one report of significant relevance to the subject of this report. Unrestricted reports can be accessed at https://oig.nasa.gov/audits/auditReports.html.

NASA Office of Inspector General

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

APPENDIX B: EARTH SCIENCE DISASTER PROGRAM 2021 DISASTER ACTIVATIONS

ESDP reported 40 disaster activations in 2021. Table 3 lists each disaster activation and includes the region the disaster occurred in, hazard type, assigned tier category, and activation date.

Table 3: ESDP Disaster Activations in 2021

Disaster Name	Region	Hazard	Tier	Activation Date
Caribbean Volcanoes	Caribbean	Volcano	1	1/6/2021
Australia Fire Season	Oceania	Fire	0	1/31/2021
India Glacier Landslide	Asia	Landslide	0	2/8/2021
Japan Earthquake	Asia	Earthquake	0	2/13/2021
Mt. Etna Eruption	Europe	Volcano	0	2/23/2021
GTM Volcanoes	Central America	Volcano	0	2/23/2021
Kermadec Islands Earthquakes/Tsunamis	Oceania	Tsunami	0	3/4/2021
Australia Flooding	Oceania	Flooding	0	3/25/2021
Piney Point	North America	Industrial	2	4/7/2021
La Soufrière Volcano	Caribbean	Volcano	2	4/9/2021
Typhoon Surigae	Asia	Tropical Cyclone	0	4/19/2021
Typhoon Tauktae	Asia	Tropical Cyclone	1	5/17/2021
Guyana Flooding	South America	Flooding	1	5/19/2021
Mt. Nyiragongo Volcano Eruption	Africa	Volcano	1	5/24/2021
Sri Lanka Oil Spill	Asia	Oil Spill	1	6/7/2021
Laos Flooding	Asia	Flooding	1	6/15/2021
Invest 92L	Central America	Tropical Cyclone	0	6/17/2021
Nepal Landslides and Flooding	Asia	Landslide	1	6/22/2021
Surfside (FL) Building Collapse	North America	Industrial	1	6/24/2021
Hurricane Elsa	North America	Tropical Cyclone	0	7/1/2021
Taal Volcano	Asia	Volcano	1	7/1/2021
European Flooding	Europe	Flooding	0	7/23/2021
Panama/Costa Rica Flooding	Central America	Flooding	0	7/26/2021
Bangladesh Flooding	Asia	Flooding	1	7/29/2021
Peru Earthquake	South America	Earthquake	0	8/1/2021
Balkan Fires	Europe	Fire	0	8/9/2021
Western US Fires 2021	North America	Fire	1	8/9/2021
Haiti Earthquake	Caribbean	Earthquake	2	8/14/2021

Disaster Name	Region	Hazard	Tier	Activation Date
Fires in Turkey	Asia	Fire	1	8/16/2021
Hurricane Ida	North America	Tropical Cyclone	2	8/27/2021
La Palma Eruption	Africa	Volcano	2	9/28/2021
California Oil Spill	North America	Oil Spill	1	10/4/2021
Hurricane Rick	North America	Tropical Cyclone	0	10/25/2021
Pacific Northwest Flooding	North America	Flooding	1	11/18/2021
Philippines Volcanic Debris Monitoring	Asia	Volcano	0	11/26/2021
Peru Earthquake	South America	Earthquake	0	11/28/2021
Mt. Semeru Volcano	Asia	Volcano	1	12/5/2021
December 10-11 Tornado Outbreak	North America	Severe Weather	2	12/13/2021
Typhoon Rai	Asia	Tropical Cyclone	0	12/15/2021
Malaysia Flooding	Asia	Flooding	1	12/21/2021

Source: NASA.

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: Assistant Inspector General for Audits

FROM: Associate Administrator for Science Mission Directorate

SUBJECT: Agency Response to OIG Draft Report, "NASA's Management of the Earth Science Disasters Program" (A-21-014-00)

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 Management of the Earth Science Disasters Program" (A-21-014-00), dated May 5, 2022.

In the draft report, the OIG makes seven recommendations addressed to the Associate Administrator for the Science Mission Directorate to direct the Earth Science Division Director to resolve.

Specifically, the OIG recommends the following:

Recommendation 1: Establish and document Program management requirements in a strategic plan and/or NPR 7120.8 project plan format for consistent messaging on ESDP [Earth Science Disasters Program] priorities, objectives, and quantifiable performance metrics.

Management's Response: Concur. NASA will develop a strategic plan for ESDP, including priorities, objectives, and quantifiable performance metrics.

Estimated Completion Date: January 20, 2023.

Recommendation 2: Perform a funding analysis of ESDP to determine if current resources are adequate to manage, oversee, and administer Program goals and objectives in accordance with its strategic plan and/or project plan.

Management's Response: Concur. NASA will perform an analysis of ESDP to assess if the current resources are adequate to manage, oversee, and administer Program goals and objectives in accordance with the strategic plan.

ESDP will use the strategy to drive the ESDP budget. NASA will use the results of this analysis in the next Planning, Programming, Budgeting, and Execution cycle.

Estimated Completion Date: February 13, 2023, following the development of ESDP's strategic plan.

Recommendation 3: In accordance with the Stafford Act, coordinate with appropriate NASA offices to develop Memorandums of Understanding [MOUs] that facilitate reimbursement agreements with applicable federal agencies that request Agency support for disaster events.

Management's Response: Concur. NASA will examine the opportunities for reimbursement agreements, coordinate with appropriate NASA offices, and pursue MOUs where appropriate.

Estimated Completion Date: May 1, 2023.

Recommendation 4: Require ESDP, in coordination with Applied Sciences Program leadership, to finalize the NASA Disasters Program Playbook and complete associated annexes and appendixes.

Management's Response: Concur. ESDP will finalize the NASA Disasters Program Playbook.

In our experience learning is continuous and the after-action reports will help us improve upon our practices; therefore, the Disasters Playbook will be refined and updated regularly to reflect this learning.

Estimated Completion Date: December 1, 2022.

Recommendation 5: Ensure ESDP provides regular training to Center disaster coordinators regarding the Playbook and expectations of application.

Management's Response: Concur. ESPD will provide regular training to Center Disaster Coordinators regarding the Playbook and its application. Notably, ESDP conducted training exercises on May 3, 2022, based on the current version of the Playbook. The Program expects this to be regular training and will be reflected in the Playbook and in the strategic plan proposed in Recommendation 1 of this report.

Estimated Completion Date: February 1, 2023, for the initial training on the final version of the Playbook.

Recommendation 6: Require the ESDP Program Manager to develop a formalized plan to capture knowledge and increase the frequency of conducting after-action activities as appropriate.

Management's Response: Concur. NASA will develop a formalized plan to regularly capture knowledge and increase the frequency of conducting after-action activities.

A key step in this activity will be determining which events require an after-action report and the level of effort required to conduct regular after-action activities.

Estimated Completion Date: March 1, 2023.

Recommendation 7: Require the ESDP Program Manager to develop a system to track lessons learned recommendations resulting from after-action assessments to ensure the recommendations are implemented and routinely evaluated for effectiveness.

Management's Response: Concur. NASA will develop a process for tracking lessons learned from after-action assessments to ensure implementation of recommendations and evaluation of effectiveness.

ESDP will consult with its primary partners to draw on their lessons learned for developing the ESDP process.

Estimated Completion Date: January 20, 2023.

We have reviewed the draft report for information that should not be publicly released. 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 report. If you have any questions or require additional information regarding this response, please contact Peter Meister at (202) 358-1557.

Sandra Connelly Digitally signed by Sandra Connelly
Date: 2022.06.11 10:17:33 -04'00'

Thomas H. Zurbuchen, Ph.D.
Associate Administrator,
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
Applied Sciences Program Director
Earth Science Disasters Program Manager

Non-NASA Organizations and Individuals

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

Government Accountability Office
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    Director, Contracting and National Security Acquisitions

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 Science and Space

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 Reform
    Subcommittee on Government Operations

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

(Assignment No. A-21-014-00)