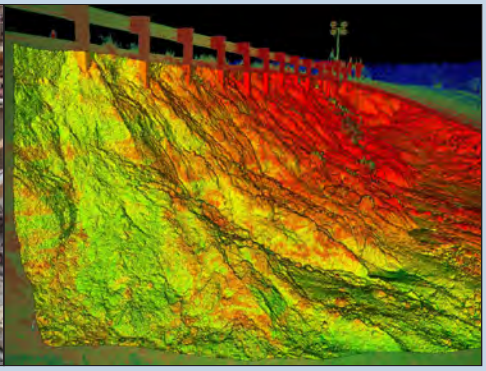

Integrating Science and Technology with Disaster Response

A Report from the Science for Disaster Reduction Interagency Coordination Group

sdr

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Preface

Most of this report was written before the COVID-19 pandemic, and readers will note the absence of pandemic-focused examples. With the response to this event ongoing, it is too soon to count particular actions as successes or best practices to share herein. But for those of us who work at the intersection of emergency response and science and technology, we recognize that it is our duty to take note of emerging successes, failures, and lessons learned to better inform our responses to future disasters.

Reflecting many of the messages in this report, the COVID-19 pandemic has underscored the critical need for those involved in responding to the emergency to work hand-in-hand with the science and technology community. For example, research performed during the crisis has provided critical information about the disease and its transmission, control measures, and treatments, as well as about public health communication at a nationwide scale. In addition, scientists from many disciplines have developed research agendas identifying questions in need of further investigation regarding the social science and public health issues of the pandemic.[1,2]

At the same time, the COVID-19 pandemic has demonstrated the need for a greater emphasis on understanding how science and emergency management can and should operate during compound disasters. For example, how does a researcher safely collect data after a major earthquake during a pandemic? How should risk communication research be applied to best inform citizens about protective actions, evacuation, and sheltering in the face of wildfire during a pandemic? How can the scientists and engineers, who normally would serve in an Emergency Operations Center to educate and counsel emergency responders on flood hazards, best do so in a socially distant or virtual environment?

The emergency management and science and technology communities are finding answers to these questions in real-time as hurricanes strike our coasts, wildfires rage across the West, tornados tear through neighborhoods, and earthquakes rattle our communities. As time passes, best practices and lessons learned will be identified from these experiences.

By continuing to learn together, the emergency management and science and technology communities can speed response, reduce suffering and economic loss, and improve long-term outcomes for the unforeseen disasters that await us over the horizon. The criticality of this mutual respect, appreciation, and learning is the focus of this report.

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[1]CONVERGE (2020b).
[2]Peek and others (2020).

Executive Summary

Each year, communities across the United States are devastated by disasters. As the frequency, severity, and cost of many of these disasters continues to increase, new collaborations and innovative solutions are needed to reduce risk. Many Federal and academic science and technology (S&T) capabilities are already integrated into disaster prevention, mitigation, response, and recovery. For example, highly accurate weather reports are critical to fighting wildfires and to evacuating communities in advance of hurricanes. Geographic Information System and remote-sensing technologies have proven invaluable for better understanding the extent and potential impact of flooding, as well as damage from earthquakes and other disasters. More can be done, however, to incorporate S&T capabilities from all quarters into disaster response to provide critical tools and information to first responders and decision makers. Steps can be taken to ensure that S&T improves over time in ways that support better decisions and preparedness for future hazards and disasters.

This report is divided into two main sections. The first, aimed at the emergency management community, summarizes what S&T capabilities currently exist to aid in U.S.-based disaster response, how these capabilities are coordinated across the Federal family and the interorganizational community, and how these assets are mobilized and funded. This section demonstrates the power of S&T in disaster response and how it may be integrated more effectively into the Incident Management System. It also highlights the importance of allowing scientists and engineers to conduct certain types of research during response. Many scientific endeavors need not be carried out during, or immediately after, a disaster, but certain ephemeral or perishable data like the baseline health of first responders should be collected to inform future responses or ongoing consequences of the present response. Perishable data can also be used to help scientists and engineers learn important lessons from disaster events. For example, knowing what engineering solutions worked or failed during a severe weather event can inform future building codes and lead to more resilient infrastructure. Allowing critical research or data collection to take place amid the unique environment of a disaster-affected area places new demands on the scientific, engineering, and response communities for communication, training, and coordination.

The second section of the report is aimed at members of the scientific and engineering communities who may be interested in conducting research during disasters. It outlines important considerations for operating within a disaster-affected area. These considerations include safety, community sensitivities, and avoiding placing further burdens on affected areas by maintaining self-sufficiency. Respectful and clear communication and collaboration between the research and emergency management communities are also underscored. It outlines a series of challenges for advancing the integration of S&T capabilities for response.

The scientific and emergency management communities have already made great strides in increasing collaboration, facilitating communication, and defining rules of engagement during disasters. Despite the different emergency management and scientific research cultures, relationships and integrated approaches are key to fully capitalizing on the use of S&T resources for disaster response.

Introduction

The science and technology (S&T) and Federal emergency management (EM) communities are coming together like never before to address some of the grand disaster challenges of our time. S&T capabilities that include Geographic Information System (GIS) and remote-sensing, meteorological, toxicological, geological, biological, and engineering expertise, as well as social and computer sciences can be brought to bear in disaster situations to reduce the short- and longer-term risks from these disaster events. Relevant S&T capabilities include the activities listed below:

- Collect and analyze (often perishable) data pertaining to a particular disaster that can provide information on current and potential outcomes,[1] as well as provide information to improve response and recovery to similar future events.
- Provide technologies that enable the collection of those data and instruments that can be used to aid response efforts.[2]

Each year, communities across the United States are devastated by disasters (National Oceanic and Atmospheric Administration [NOAA], 2015). Using

[1]For example, rapid assessments of vaccines administered during an epidemic, complex exposures, weather forecasts, and projections of earthquake aftershocks.

[2]For example, unmanned aerial vehicles to aid reconnaissance, real-time or near real-time mapping capabilities, and communications technologies to allow collaboration and reporting at all levels.

S&T capabilities is critical to effective response and speeding recovery as the frequency, severity, and cost of many of disasters continues to increase (Munich RE, 2018; Coronese and others, 2019). These capabilities will continue to grow through innovation and broader application. Facilitating scientific research during disasters can help reduce the effects of subsequent disasters and may shed light on how response and recovery efforts can be improved. Steps taken to ensure that the S&T community and the EM community can support each other during disaster responses will enable these advances to continue at a pace that can match that of disasters our Nation may face in the future. This report highlights the existing collaborations and exchanges that occur between these two communities, and identifies areas where new collaborations and innovative solutions could improve these interactions over time.

Origin and Purpose of this Report

In 2014, the National Science and Technology Council's Subcommittee on Disaster Reduction (SDR) formed the National Preparedness Science and Technology Task Force to "act as the interagency conduit to more fully integrate S&T into all facets of national preparedness across all Federal departments and agencies," including "[a]ssessing the current status of Federal S&T investments across the five PPD-8 mission areas" (Science for Disaster Reduction, undated, p. 1–2; U.S. Department of Homeland Security, 2018). The National Preparedness Science and Technology Task Force published the 2016 Office of Science and Technology Policy (OSTP)-issued report, "Identifying Science and Technology Opportunities for National Preparedness" (U.S. Subcommittee on Natural Disaster Reduction, 2016). To complement the 2016 OSTP report, SDR[3] subsequently established a writing team to focus on the current state of and opportunities for further integration of S&T during U.S.-based disaster response in support of the National Response Framework (NRF). This report, "Integrating Science and Technology with Disaster Response," is the result. Representatives from agencies across the Federal disaster response and recovery communities contributed to this report, include those listed below:

- Department of Commerce (DOC)
  - National Institute of Standards and Technology (NIST)
  - National Oceanic and Atmospheric Administration (NOAA)
- Department of Defense
  - U.S. Army Corps of Engineers (USACE)
- Department of Health and Human Services (HHS)
  - National Institutes of Health (NIH)
- Department of Homeland Security
  - Federal Emergency Management Agency (FEMA)
- Department of the Interior (DOI)
  - Bureau of Land Management (BLM)
  - U.S. Geological Survey (USGS)
  - Office of Emergency Management (OEM)
- Executive Office of the President
  - Office of Science and Technology Policy (OSTP)
- U.S. Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA)

This publication is intended for two audiences: (1) the Federal EM community,[4] and (2) the S&T community, including Federal and State scientific organizations, as well as academic institutions.[5] This report recognizes that although scientists and emergency managers prioritize the protection of human life and property over scientific discovery, there are often important cultural differences between these two groups (for example, Mease and others, 2017; Colwell and Machlis, 2019). Although the divide between these two groups can sometimes be blurred or overlapping, for the purposes of this report, we treat them as distinct. This report is divided into two main sections per these two audiences. The aim of this document is to continue to build mutual understanding between these two groups to enable more effective future collaborations.

[3]In 2019, the SDR transitioned out of the National Science and Technology Council structure, becoming the Science for Disaster Reduction interagency coordination group.

[4]Although State, Tribal, local, and territorial emergency management personnel could greatly benefit from, and offer benefit to, innovations in relevant S&T, addressing the interactions between these groups and the S&T community is beyond the scope of this report; however, building relationships across these sectors is important to community response to disaster events and deserves further attention.

[5]The interactions between these two groups and the private sector was deemed outside the scope of this report; however, the private sector should not be discounted because it collects and stores critical information and is increasingly a part of disaster response and should be included in future considerations.

Section 1: How Science and Technology Helps Emergency Response

For the Federal EM community, this report aims to strengthen awareness and understanding of:

- How incorporating S&T enhances the Federal Government's ability to respond to disasters quickly and effectively.
- How to integrate S&T into EM activities to improve response; and why it is important, where feasible, to enable S&T research during response.

Section 2: Conducting Research in Disasters

For the S&T community, this report aims to further understanding of:

- The important logistical and contextual constraints under which the response community must work during a disaster response, including limited time, attention, and resources.
- The established and necessary structures and protocols through which EM is enacted.
- What S&T research must be done during a disaster (and what does not need to be done).
- How S&T can effectively contribute to disaster response.

This report draws on best practices and lessons learned from various agency activities and disaster events, focusing primarily on response, where needs and opportunities for contribution seem most pressing. It draws on previous work in this area (annex 2). Building from this foundation, this report includes a series of challenges to the EM and S&T communities to consider in advancing the integration of S&T capabilities during disaster response (annex 3).

Section 1: How Science and Technology Helps Emergency Response

1.1 The Federal Approach to Preparedness and Response

The United States has developed an integrated, whole-community, all-hazards approach to disaster preparedness, called the National Preparedness System (NPS; FEMA, 2020c), which is organized around five mission areas: prevention, protection, mitigation, response, and recovery. Although S&T informs all these mission areas, this report focuses on response.

Five National Planning Frameworks correspond to the five NPS mission areas, and each framework uses the same language to specify the role of S&T in the mission areas: "[S]cience and technology (S&T) capabilities and investments are essential for enabling the delivery and continuous improvement of National Preparedness. The whole community should design, conduct, and improve operations based on the best, most rigorous scientific data, methods, and science-based understandings available. *** In addition, coordination across the whole community, including scientific researchers, will ensure that scientific efforts are relevant to National Preparedness." (FEMA, 2016d, p. 46).

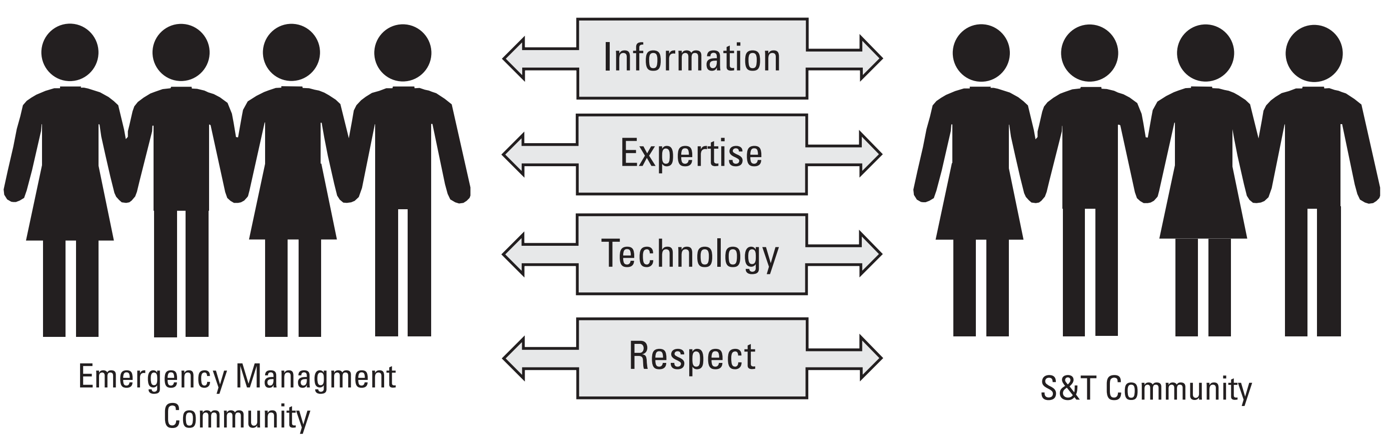


Figure 1. Exchange between the emergency management and science and technology (S&T) communities.

Given the roles of S&T described above, the S&T community works to address two separate but related challenges to meet its NRF responsibilities:

- ensuring that S&T capabilities are effectively mobilized in support of disaster responses; and
- ensuring that disaster-relevant S&T capabilities advance to improve future preparedness and responses.

This distinction recognizes that although some S&T capabilities can be immediately mobilized to support disaster response, some S&T research needs to take place during a response that may not inform that particular response situation. Instead, the information gained from that research can advance preparedness for future response and recovery efforts. For example, collecting information on how certain building structural systems were affected by an earthquake may not have immediate use in the response to an earthquake. However, gaining this information can inform building codes and retrofit capabilities to ensure that earthquake-prone areas have stronger, safer buildings in the future.

Along similar lines, understanding short-and-long term health effects of disasters can improve effective development and allocation of resources to better protect communities and lessen adverse health consequences in the future.

1.2 What Science and Technology Provide for Response

S&T can and does support all the NRF responsibilities outlined in section 1.1 in a variety of ways. S&T is regularly included in a variety of Emergency Support Functions (ESFs) including ESF-3, public works and engineering (FEMA, 2008a); ESF-5, information and planning (FEMA, 2016a); ESF-8, public health and medical services (FEMA, 2008b); ESF-10, oil and hazardous materials response (FEMA, 2016b); ESF-11, agriculture and natural resources (FEMA, 2008c); and ESF-12, energy (FEMA, 2016c). The types of reliable, situation-specific decision-support information and questions that can be answered by S&T in disaster situations include:

Decision-Support information	Relevant Questions
Hazard Detection, Characterization, and Situational Awareness	• What has happened? • What are the hazards and potential risks? • What are the uncertainties in what is known?
Forecasts and Anticipated Consequences	• How will the hazards and risks evolve over time and over a given geographic area? • How does the situation compare to historical analogs? • What are the potential scenarios? • What information needs to be shared with emergency managers to support critical decisions?
Risk Assessment	• What or who might be affected? • How do socioeconomic vulnerabilities affect the distribution of risk and impacts? • What are the potential cascading consequences? • What is the range of challenges that should be prepared for?
Risk Communication	• What are the most effective means of communicating with impacted diverse populations? • Why do people respond differently to different hazards and (or) to warnings and directives given during a response? • How do emergency managers want information delivered to them to make timely, critical decisions?

Decision-Support information	Relevant Questions
Response	• What are the options for risk reduction? • What are the pros and cons of the available options? • Which responses are productive, and which are not? • Are the interventions working, and if so, how well?
Risk Mitigation	• What will enable faster, safer, and more effective response and recovery operations? • What can be done to increase redundancy and flexibility in response functions?
Evaluation of Information	• How credible and reliable is the information provided by outside sources? • How should model and sensor data be interpreted, and how are variations explained?

1.3 Current Uses of Science and Technology for Response

Some S&T support tools are so routinely used by emergency managers and responders that users may take them for granted. Weather and flood forecasts, fire-behavior forecasts, air monitoring, oil spill dispersion, and risk assessments related to contaminants, pathogens, and radioisotopes are familiar examples. For many of these types of "normal" hazard assessment tools, decision makers already know (or can be made aware of) how to access them when an incident begins to unfold. The disaster-response exercises that are conducted as part of the NPS help build and maintain this awareness. However, larger-scale disasters can often push the edges of what is known, creating unusual or unique conditions that require innovative solutions, which the S&T community can help develop.

As the following examples show, S&T research and data collection can enhance response to natural, technological, and adversarial hazards. They also illustrate how information collected during the response can be useful in improving future response strategies.

Examples of How Science and Technology Capabilities Have Enhanced Disaster Response

Widespread Inland Flooding

Photograph credit: Steve Zumwait, Federal Emergency Management Agency.

- **Description:** The summer of 2019 brought extended cold, wet rainfall to multiple central States resulting in prolonged (February to July) regional flooding that damaged many cities and over a million acres of cropland.
- **How S&T Mattered During Response:** Streamgage data were used to predict impending flooding, enabling accurate warnings. Those data were also used to predict when floods would recede, so citizens and communities could plan for return and recovery.
- **How S&T Mattered After Response:** High-water mark, seepage, and sand-boil data were used to make decisions about how to mitigate risk from future floods, informing actions like elevating structures and moving critical infrastructure. High-water mark data were also used for insurance payment decisions.
- **S&T Capabilities Used:** Water-monitoring networks and ground observations for documenting effects to flooded areas; aerial monitoring for detecting seepage and sand boils; documenting flood effects including extent of damage, and population dislocation.

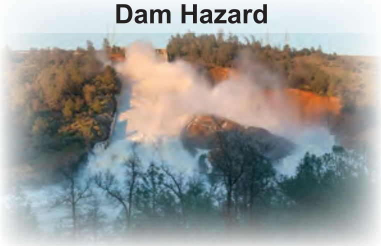
Examples of How Science and Technology Capabilities Have Enhanced Disaster Response—Continued

Volcanic Eruptions

Photograph credit: Public domain.

- **Description:** Hawaii experienced its longest-recorded eruptive event with the 107-day eruption of Kilauea in 2018. Despite major earthquakes, large volumes of lava erupting into residential neighborhoods, ash plumes reaching 30,000 feet in the air, and record levels of volcanic gases, few people were injured, and no one was killed (Neal and others, 2019).
- **How S&T Mattered During Response:** Volcano scientists identified where lava and dangerous gases would be heading based on volcanic and seismic monitoring data, as well as long-term research on the volcano. They directly advised State/county officials who then ordered evacuations, saving lives and property. Also, toxic volcanic gases were monitored by Federal and State scientists, allowing health officials and the public to take precautions for public health and sensitive populations.
- **How S&T Mattered After Response:** High-resolution light detection and ranging (lidar) surveys of topographic changes resulting from summit collapse and lava flows enabled scientists to model where new lava flows might travel. This supported decisions about recovery and long-term risk mitigation such as relocation of structures and county planning for road rebuilding. Calculations of lava thickness and cooling times also informed reconstruction. Geochemical analysis of the water in the new crater lake and monitoring of volcanic gases are important for hazard mitigation planning because they can help indicate future eruptions and localized explosive events. Ongoing geophysical investigations of changes in the magmatic system are being used to forecast future eruptive activity.
- **S&T Capabilities Used:** Volcanic and seismic monitoring via sensor networks; volcanic gas emissions monitoring; and real-time monitoring of lava flows via satellite and Unmanned Aerial Systems (UASs).

Dam Hazard



Photograph credit: California Department of Water Resources.

- **Description:** In February 2017, more than 1 foot of rain fell in the river basin feeding Lake Oroville in Northern California in just 4 days. The high inflow resulted in the failure of components of the Oroville Dam facility, potentially threatening the lives and property of local residents.
- **How S&T Mattered During Response:** A wide range of Federal S&T experts directly informed State and local officials as they planned their responses to the event, enabling them to make effective and timely decisions about whether, when, and to where evacuations should occur. Their advice included information specific to medically at-risk individuals. These experts worked with emergency managers to develop options to mitigate potential loss of life and property as the event evolved.
- **How S&T Mattered After Response:** Investigations regarding why and how certain dam components failed and the geology underlying the dam were critical to informing rebuilding and repair efforts, as well as future dam-building.
- **S&T Capabilities Used:** Weather modeling and forecasts; rapidly deployed stream and river measurements; structural failure modeling; mapping medically at-risk individuals; and remote sensing.

Examples of How Science and Technology Capabilities Have Enhanced Disaster Response—Continued

Photograph credit: Denise Gould, U.S. Air Force.

- **Description:** After the attacks of September 11, 2001, there was significant concern that the dust that covered much of lower Manhattan might contain amphibole asbestos, threatening the pulmonary health of emergency response crews and residents.
- **How S&T Mattered During Response:** Federal scientists developed maps showing potential dispersion patterns of hazardous materials including asbestos. These maps helped emergency managers and health officials assess health risks and form response and mitigation strategies (Clark and others, 2002; Meeker and others, 2006).
- **How S&T Mattered After Response:** Findings based on the baseline health data gathered from emergency responders immediately after the event have improved exposure assessments, mitigation strategies, training, and worker protections nationwide. Studies of how buildings, infrastructure, and people behaved in the attacks resulted in 40 building code improvements to prevent similar disasters in the future. Evacuation pattern studies have improved emergency preparedness (NIST, 2019a).
- **S&T Capabilities Used:** Identifying bioaccessible and biodurable components of the dust; collecting baseline health data, including biological samples, of emergency personnel; studying building construction, materials, as well as the structural and technical conditions that contributed to the collapse-related outcomes; and studying evacuation behavior.

Photograph credit: Morgana Wingard, U.S. Agency for International Development.

- **Description:** The 2014 outbreak of Ebola in West Africa was the largest and most complex in history. The highly infectious disease initially spread to three capital cities on the African continent. All told, over 28,000 people became infected, and over 11,000 people died across 7 countries. Because the disease spread rapidly, there was an immediate need for treatment options and for effective, culturally appropriate communication strategies and interventions.
- **How S&T Mattered During Response:** Treatment and vaccination options that were being studied but not yet fully assessed were rapidly evaluated then successfully deployed to the affected nations. Also, based on rapid research and development, improved worker protections were devised and widely implemented to reduce the risks of exposure and disease. Anthropological research performed before and during the response provided crucial social, cultural, and political context to the teams responding to the epidemic. This information helped responders ensure that they were making locally appropriate interventions to address the outbreak effectively (European Commission, 2015; read more at http://www.ebola-anthropology.net/).
- **How S&T Mattered After Response:** Further testing and evaluation, based on findings developed during the outbreak, led to the licensing of the first Ebola vaccine. This vaccine is now being used to fight the disease in West and Central Africa. Follow-on research on risks of exposure for health workers has led to modifications of worker personal protective equipment (PPE) and activities that have saved lives during subsequent outbreaks.

Examples of How Science and Technology Capabilities Have Enhanced Disaster Response—Continued

Public Health Disaster—Continued

- **S&T Capabilities Used:** Health and public health professionals deployed rapidly to conduct clinical trials to assess the efficacy of promising but not-yet-approved interventions; shared samples to support research; and conducted epidemiological and social-science research to better understand how to control the spread of the disease in the future. Research was also performed to evaluate risks to front-line workers. Anthropologists shared ethnographic research related to social and behavioral practices (for example, caregiving, funerary practices, cleaning, food preparation, and health-related practices) with the U.S. Federal agencies who responded to the event; they were also included in “source investigations” seeking to find the origin of the animal-to-human transmission (Abramowitz, 2017).

Wildland Fire and Post-Fire Debris Flow

Photograph credit: Kari Greer, U.S. Forest Service.

- **Description:** The Thomas Fire burned over 280,000 acres in California’s Ventura and Santa Barbara Counties in the winter of 2017–18. The fire destroyed over 1,000 structures and forced thousands of people to evacuate. Immediately after the fire, heavy rainfall caused destructive and deadly debris flows and floods that killed 23 people and injured 167 others in Montecito, California, and closed Highway 101 for several days (Kean and others, 2019).
- **How S&T Mattered During Response:**
  - **Fire Response:** Fire behavior models informed by weather, terrain, fuels/vegetation, remote-sensing, and fire-detection data were provided to responders to help them plan their fire response activities. A newly developed system that integrated multiple GIS layers enabled responders to make decisions based on a wide array of data. Other technologies allowed emergency managers to track fire-related resources in real time, increasing the speed and safety of response.
  - **Post-Fire Debris Flow:** GIS data showing debris flow potential and magnitude informed evacuation and emergency response planning (U.S. Forest Service, 2020). These hazard assessments also informed public outreach, watches and warnings delivered in advance of heavy rainfall. The National Weather Service (NWS) models and tools for forecasting and monitoring heavy rainfall provided critical lead time prompting the largest evacuation in Santa Barbara County history.
- **How S&T Mattered After Response:**
  - **Fire Response:** Lidar 3D Elevation Program data was acquired after the fire to characterize changes to vegetation (fuel) and terrain to support post-fire recovery and new forecasts of fire risk. These data were used to improve models that contributed to subsequent fuels-reduction and other fire prevention and mitigation activities.
  - **Post-Fire Debris Flow:** After the fire, the USACE conducted a Flood Plain Management Study that resulted in recommendations for improvements that would allow structures to withstand potential future debris flows. Also, the USGS and Los Padres National Forest staff developed a Burned Area Emergency Response (BAER) plan that was based on debris flow and hydrological models in areas where landscapes were ravaged by the fire. This plan was used to secure additional resources for mitigation measures in areas with increased risk.

Examples of How Science and Technology Capabilities Have Enhanced Disaster Response—Continued	
Wildland Fire and Post-Fire Debris Flow—Continued	• **S&T Capabilities Used:** • **Fire Response:** Fire behavior modelling and remote sensing of terrain and vegetation; WildCAD (http://www.wildcadsupport.net/login.asp), a Computer Aided Dispatch system that brings together numerous GIS layers for more effective fire dispatch; Integrated Reporting of Wildland-Fire Information system that integrates all available wildland fire data (Forests and Rangelands, 2021); Interagency Fuel Treatment Decision Support System (https://iftdss.firenet.gov/landing_page/), a web-based application to make fuels treatment planning and analysis more efficient and effective, providing access to data and models in one interface. • **Post-Fire Debris Flow:** Integration of recent innovative modeling capabilities developed from ongoing research and development focused on improving knowledge and modeling capabilities after wildfire for flood risk management (Kean and others, 2019).

1.4 Integrating S&T Support into Existing Response Structures

The National Incident Management System (NIMS, https://www.fema.gov/national-incident-management-system) makes clear that a unified incident command approach should be established for any disaster incident to ensure coordinated and unified objectives, strategies, priorities, resources, and logistics, and to provide a "common operating picture." Any common operating picture includes shared situational awareness and information-sharing activities to provide the best possible support for plans and decisions. As the examples in the previous section show, S&T plays a significant role in providing critical components of situational awareness to incident command.

Two primary mechanisms are available to help command units integrate S&T advice and expertise into their incident command structures:

- **S&T advisors (FEMA, 2019, 2020d):** personnel with the training and capability to provide S&T support for response decisions. S&T advisors integrate into the Incident Command System (ICS) to give Unified Command or equivalent advice in near-real time. They act as a liaison between EM authorities and the S&T community.
- **S&T advice units:** groups that focus on a particular hazard and are able to quickly mobilize to provide information on a particular event. The information provided by these units is used by the S&T advisors.[6]

Beyond these roles, which are explicitly included in the ICS, several types of agency-level and interagency mechanisms have evolved to ensure that S&T-related, mission-relevant capabilities are developed, maintained, and made available when decision support is needed during disaster. These include:

- Interagency coordinating bodies.
- Real-time communication including phone, video, text, and data exchanges.
- Mission assignments (pre-scripted or not) to ensure S&T during response is appropriately funded and activated at the correct time.
- Vetting and organizing scientists and engineers with relevant subject-matter expertise for deployment to support disaster response.

The following sections (1.4.1 to 1.4.5) provide additional detail and examples on how S&T information is collected, communicated, funded, and organized during disaster response.

[6] Although the Science and Technology Advisor is a position identified in NIMS, the concept of an S&T advice unit is not; however, these units are critical to coordinating information and delivering it during a response.

1.4.1 Communicating S&T information: Science and Technology Advisors

Since 2017, NIMS has explicitly allowed for Incident Commanders and Unified Commands to appoint S&T advisors to help monitor incident operations and advise on the integration of S&T into planning and decision making. Embedding an S&T advisor[7] (or teams of advisors) in a Unified Command Staff enables direct observation of needs and timely communication. S&T advisors embedded with Command Staff can:

- Anticipate S&T information and capabilities that would be helpful to decision makers;
- Translate S&T inputs into useful information for Incident Commanders and Emergency Operation Center Managers;
- Translate Incident Commanders' operational needs into language the S&T community better understands;
- Draw on the expertise and skills of others—including experts affiliated with the National Academies of Science, Engineering, and Medicine (NASEM), universities, professional associations, and (or) the private sector—to acquire the most current and relevant knowledge and experience; and
- Call for, organize, or facilitate real-time S&T inquiries—such as rapid vaccine testing or landslide potential assessment—to assist response.

[7]S&T Advisors are not always employees of the Federal government. Although Federal scientists and engineers are most lokely to be S&T Advisors amid wide-spread or complex incidents, non-Federal S&T Advisors may be brought in to offer advice on less complex or on small-scale State or municipal incidents.

Examples: Responsibilities of Science and Technology Advisors in a Disaster

A list of major responsibilities for S&T advisors, beyond serving as subject-matter experts:

- Have completed baseline training and keep up to date on incident management and hazard safety practices, as demonstrated by applicable certification/recertification
- Review common responsibilities identified for all incident management personnel
- Attend planning meetings
- Help identify and prioritize critical data gaps
- Determine opportunities for S&T to provide needed information and resource needs
- Provide forecasting regarding the hazard (trajectory, effects, and probabilities)
- Seek multidisciplinary perspectives and best strategies to address the S&T issues affecting the response
- Identify and (or) prioritize populations, resources, and assets that are at risk from the hazard
- Integrate knowledge from Government agencies, universities, nongovernmental organizations, community organizations, and industry to assist the response or recovery leaders in evaluating the hazards, risks, and mitigation strategies associated with the incident
- Maintain a log of activities and submit to documentation

This list is adapted from U.S. Coast Guard (2014) and NOAA's directives for Federal On-Scene Coordinators (NOAA, 2015) and NWS Incident Meteorologists (IMETs; NWS, 2020).

Given the whole-community approach to preparedness and response, S&T advisor capabilities need to be workable at all levels of the NPS. When an event presents such an unusual or significant threat to the Nation that the President engages in command, the Director of the White House OSTP serves as the Science Advisor and draws on the resources available throughout the Federal government and beyond. More routinely at the Federal level, the Command Staff that typically need access to S&T resources include FEMA's National Response Coordination Center, Regional Response Coordination Centers, and Joint Field Offices. At Tribal, State and local levels, the relevant unified command bodies may have different names and may function in State or Tribal Emergency Operation Centers.

Several Federal agencies have already adopted S&T advisor-type roles, or S&T advisory teams with close links to incident commands, to meet the needs described above. Examples are below.

Example Science and Technology Advisor Capabilities

Title: Scientific Support Coordinator

Expertise Provided: Hazardous spill response effects as well as consequence management from intentional acts using weapons of mass destruction.

Responsibility: Oversees S&T support in spill response. Works across disciplinary specialties to coordinate a wide range of scientific issues in such a response.

Agencies: These coordinators are typically provided by the EPA or NOAA

Title: Science Liaison

Expertise Provided: Natural and technological hazards

Responsibility: DOI is currently in the process of approving positions in the "Science Liaison Technical Specialists" category of its Incident positions qualifications guide. People in these positions would act as liaisons between the scientific communities, Incident Management Teams, Emergency Operations Centers and (or) the Joint Information Center. These people would disseminate technical information and provide information needed for incident planning and response activities. The Agency Representative and Science Liaisons would ensure appropriate reach back to scientists who are not onsite but whose expertise are critical to decision making during a response.

Agencies: DOI

Title: Incident Meteorologists (IMETs)

Expertise Provided: Provide weather briefings and forecasts to incident responders and command staff at wildfires and other incidents. IMETs collaborate closely with State and local fire-control agencies, as well as the U.S. Forest Service and other Federal agencies to keep firefighters safe by interpreting weather information, assessing its effect on the fire, and communicating it to fire crews.

Responsibility: Once onsite, IMETs become key members of the incident command teams and provide continuous meteorological support during the incident. Each IMET deployment lasts around 2 weeks or until the wildfire is considered contained.

Agencies: NOAA, NWS

Example Science and Technology Advisor Capabilities—Continued

Title: Liaisons to FEMA

Expertise Provided: Hydro-meteorological, space weather, geophysical, environmental health, hydrological, and biological sciences; translates complex information into actionable concepts. Provides relevant data for decision making and damage assessment support.

Responsibility: NOAA's Liaisons to FEMA serve as the initial NOAA point of contact on behalf of the NWS and National Ocean Service leadership and subject-matter experts across NOAA line and program offices. The Liaisons also serve as technical specialists on behalf of NOAA during activation of FEMA's National Response Coordination Center. These liaisons also maintain situational awareness of hydro-meteorological and space weather threats over the United States and territories to assess potential hazards and related impacts while providing decision support on these issues with little advance notice and may provide decision support tools and data for coastal response. USGS liaisons to FEMA maintain situational awareness of geophysical or relevant hydrological, biological, or environmental health hazards to provide information to support data-driven decision making. Additionally, the liaisons serve as the initial USGS point of contact for the agency and provide reach-back to agency expertise during incidents.

Agencies: NOAA, USGS

Title: HHS Disaster Leadership Group

Expertise Provided: Public and human health; emergent health concerns

Responsibilities: The Assistant Secretary for Preparedness and Response leads a trans- HHS Agency and Interdepartmental Disaster Leadership Group that allows for HHS-wide deliberations on time sensitive issues to inform strategic considerations and policy recommendations made to the HHS Secretary.

Agencies: HHS as well as other Federal partners

Title: Emergency Preparedness and Response Team

Expertise Provided: Demographic and economic data analysis

Responsibilities: Quickly martial Census Bureau demographic and economic data for the geographies affected by the disaster. This is done quickly by using user-friendly data tools that have been deemed Mission Critical by the DOC.

Agencies: U.S. Census Bureau

1.4.2 Integrating S&T into the Incident Command System

Better integrating S&T into the ICS (see figure 2) ensures that planning and operational decisions during an event are made based on the best-available scientific information. Science and engineering can inform almost every aspect of the ICS. For example, hazard exposure information can inform Planning and Logistics Section Chiefs as to how to select locations for shelters, equipment, and event-support stations that are out of harm's way (removed from landslide hazard zones, areas of potential contamination, and so on). Using their expertise, scientists involved in the event can inform the Safety Officer as to potential cascading hazards, appropriate personal protective equipment, and recommended training to ensure the safety of emergency management personnel. Engineers can offer insights regarding the structural integrity of affected structures or the potential effects of various chemicals on emergency response equipment and vehicles.

Situating scientists and engineers within the ICS is also critical to coordinating the collection and delivery of critical disaster-related data with response activities, ensuring that the protection of life safety and human property are always prioritized. Positioning scientists and engineers within ICS can help keep S&T experts performing field-based data collection safe, accounted for, and well supported from a logistics standpoint. Often, emergency managers quickly move disaster areas to a controlled boundary where access is limited. Without the help of the EM community, scientists and engineers who need to collect perishable data quickly may not have access to the affected area. Integrating S&T positions and teams within the ICS ensures that emergency operations and planning staff can assist these teams in case of emergency, and are aware of where S&T teams are operating, what logistical support they might need, and what safety concerns they may have.

As noted above, the NIMS identifies an S&T advisor as a position that can be added to the Command Staff to inform the Incident Commander (FEMA, 2017, p. 85). Having an appointed S&T advisor to the Incident Commander is an important means of coordinating, communicating, and prioritizing scientific information transfer and activities during or directly after an event. This advisor can help prioritize the collection of scientific data (for example, data critical to life safety versus data for long-term research). The S&T advisor can also reach back to the greater S&T community for information to inform incident response. For Presidentially declared emergencies or major disasters under the Stafford Act where ESFs are activated, FEMA would mission assign an ESF that is led by a Primary Agency, and that agency would provide responders for a specific incident or would reach out to its Support Agencies to provide specific expertise or resources. Primary Agencies and Support Agencies are identified in the NRF. Those response resources would all operate under NIMS, as stated above.

The hollow boxes within figure 2 show where S&T may fit into the ICS. The S&T advisor and his/her team of onsite and offsite scientists, engineers, communication specialists, liaisons, and technical specialists can help coordinate S&T and EM activities, as well as the communication of scientific information to incident command. In the Operations Section, the deployment of field technicians and monitoring equipment can be overseen by a Deputy Operations Chief in charge of S&T. In the Planning Section, the Science Unit can perform specialized, tailored situational assessments including long-term risk probabilities, and translation of the latest real-time monitoring and modeling information. This unit can also plan for the collection of critical perishable data in coordination with the larger emergency management response.

ICS is scalable, allowing for the appropriate size response for a given incident. Likewise, S&T integration into ICS is scalable. For some incidents where fieldwork is not needed, only a S&T liaison or technical specialist may be necessary to provide reach-back from Incident Command to the S&T community. In other cases, the S&T community may need to stand up its own management team to coordinate a large S&T response (see annex 3 for an example of science management team organization).

Scientists, engineers, and emergency managers are responsible for effectively integrating science into the ICS. Scientists and engineers need to be trained in ICS to understand appropriate terms, hierarchies, and protocols. Emergency managers need training on how S&T can enable faster and scientifically supported decision making. By working together to incorporate S&T into the ICS, the whole community can benefit from more efficient and effective response.

1.4.3 Collecting S&T Information: S&T Advice Units

Several Federal agencies have created organizational units dedicated to S&T support for hazardous incidents. Such groups develop and maintain expertise and capabilities that are specific to disaster and crisis situations. They also tend to maintain awareness of and relationships with Federal and university-based research communities so that, when specialized knowledge or tools are needed, they can be used to support rapid and effective deployment when the time arises. Below are several examples from different agencies.

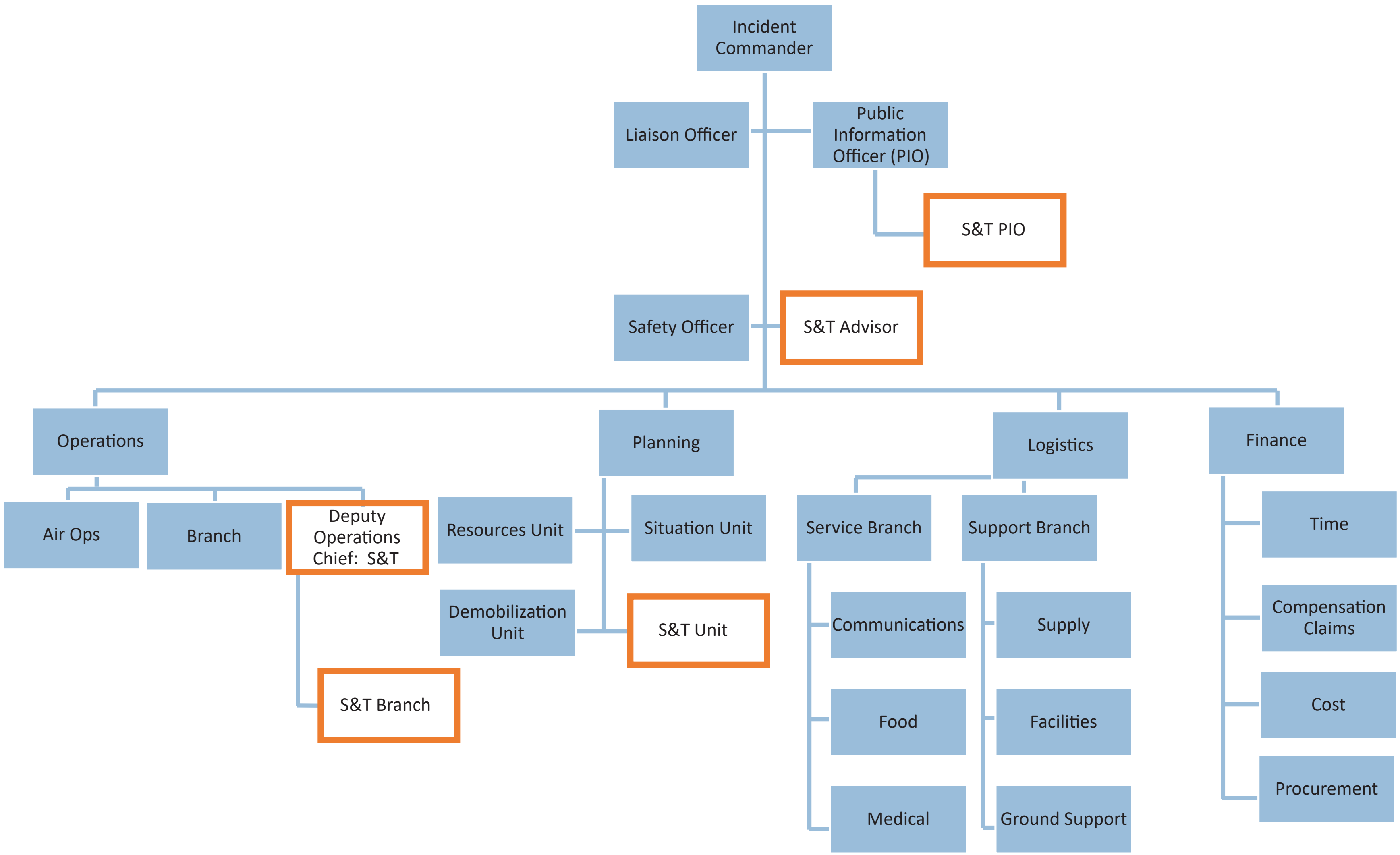


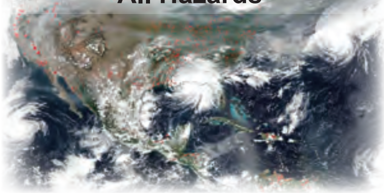
Figure 2. Incident Management System (ICS), and potential areas for science and technology (S&T) integration in hollow boxes. Modified from Federal Emergency Management Agency (2018).

Example Federal Science and Technology Advice Units

Issue Addressed	Responsibilities and Agencies
Meteorological Events  Photograph credit: Jason Weingart, public domain.	• **Agencies:** NOAA, NWS • **Responsibility:** Provide both onsite and remote impact-based decision support services to decision makers for high-impact weather events, and for weather support of high-profile large gatherings in direct support of, and at the request of, local and State EM, FEMA, and other governmental organizations. • **Who:** NWS Office Warning Coordination Meteorologists along with additional staff that have been trained on providing this type of service. • **How:** NWS staff engage with partner groups throughout the year to better understand their thresholds and needs, so that they can more effectively support them when called upon. Staff will often deploy to incident command centers or provide remote support through phone and webinar briefings when an onsite deployment is not needed or feasible.
Wildland Fire Emergency Stabilization  Photograph credit: U.S. Geological Survey.	• **Agencies:** U.S. Forest Service, National Park Service, Bureau of Land Management, U.S. Fish and Wildlife Service, USACE, State, Tribal governments, and local agencies • **Responsibility:** BAER teams address emergency stabilization and rehabilitation related to post-wildland fire through coordinated efforts between Federal, state, and tribal governments, as well as local agencies and emergency management departments. BAER teams recommend emergency stabilization actions and long-term prescriptions during a wildfire or shortly after wildfire containment to stabilize and rehabilitate natural and cultural resources, protect public safety, and prevent further degradation of the landscape. A specific example of a BAER assessment includes providing hydrologic analyses of the altered vegetative and soil conditions and implement flood control measures for both agency missions and state assistance. • **Who:** BAER teams are staffed by specially trained professionals: hydrologists, soil scientists, engineers, biologists, vegetation specialists, archeologists, and others who evaluate the burned area and prescribe emergency stabilization treatments. • **How:** An incident management team or land management agency may request a BAER team during an incident where post-incident conditions may threaten human health and safety, or damage has occurred to natural and cultural resources.
Public Health Crises  Photograph credit: Centers for Disease Control and Prevention, public domain.	• **Agencies:** HHS, NIH, NIH Disaster Research Response (DR2) Program • **Responsibility:** NIH DR2 Program focuses on improving time-critical human health related data collection, research, and information gathering to support response and recovery for disasters and health emergencies (Miller and others, 2016). • **Who:** This program focuses on leveraging expertise from across NIH, other HHS agencies, as well as the academic and health professional community across the United States to help address acute and longer-term health effects and community concerns. • **How:** The NIH DR2 Program facilitates rapid coordination of health experts to assess data gaps and research priorities, dissemination of information to Government officials and the public, improved capacity for timely research through publicly available repositories of data collection tools, Institutional Review Board (IRB) guidance, protocols, and funding, and training for scientists and other stakeholders.

Example Federal Science and Technology Advice Units—Continued	
Issue Addressed	**Responsibilities and Agencies**
Health Emergencies  Photograph credit: International Atomic Energy Agency Imagebank, public domain.	• **Agencies:** HHS, Assistant Secretary for Preparedness and Response • **Responsibility:** The Science Preparedness Interagency Research Team develops rapid research mechanisms, policies, and infrastructure to expedite and enhance the timeliness of research efforts during public health emergencies. • **Who:** Consists of various HHS agency science representatives. • **How:** The Science Preparedness Interagency Research Team provides a central forum for the coordination of science preparedness, response, and recovery and facilitates the coordination of common projects between interagency stakeholders.
Environmental Crises  Photograph credit: U.S. Coast Guard.	• **Agencies:** DOI • **Responsibility:** The DOI Strategic Sciences Group (SSG) provides Departmental leadership with scientific expertise during environmental crises. The SSG develops science-based scenarios showing short- and long-term chains of consequences for coupled human and natural systems. The SSG uses the scenarios to provide actionable interventions to decision makers for response and recovery planning. • **Who:** The SSG convenes a multidisciplinary, event-specific "crisis science team" of experts from both within and outside the Government. • **How:** Activated by Secretarial Order.
Harmful Algal Blooms  Photograph credit: U.S. Geological Survey (Landsat 8).	• **Agencies:** NOAA • **Responsibility:** NOAA provides critical detection tools, forecasts, and technical knowledge about Harmful Algal Blooms (HABs) to State and local public health managers when they occur. HAB capabilities include an Analytical Response Team and an HAB Event Response Program. Analytical teams allow responses to be tailored to each unique event and assist decision makers in making rapid and informed decisions with regards to the environment, human health, and commerce. • **Who:** National Centers for Coastal Ocean Science. • **How:** NOAA's National Centers for Coastal Ocean Science provides analytical response through a partner network to alert, identify, and quantify suspected HABs; maintain monitoring and modeling capabilities; and provide limited funding to support Federal, State, and local officials that manage and understand HAB events.
Pollution and Contaminants Release  Photograph credit: Brocken Inaglory, GNU Free Documentation License.	• **Agencies:** EPA • **Responsibility:** Reachback for Emergency Response addresses complex environmental problems and disasters. • **Who:** RACER draws on scientific and engineering researchers and technical experts from across EPA's 10 national laboratories and centers. • **How:** RACER is coordinated through EPA's Office of Research and Development.

Example Federal Science and Technology Advice Units—Continued	
Issue Addressed	**Responsibilities and Agencies**
Volcanic Eruptions  Photograph credit: Christoph Kern, U.S. Geological Survey.	• **Agencies:** USGS and U.S. Agency for International Development (USAID) • **Responsibility:** The USGS/USAID Volcano Disaster Assistance Program (VDAP) mobilizes to contribute expertise and equipment to other nations in times of crisis. VDAP scientists and their colleagues conduct field work, analyze geophysical data and satellite observations, and consider historical observations to help develop early warning capabilities. • **Who:** USGS volcano scientists and local counterparts. • **How:** Co-funded by USAID's Office of U.S. Foreign Disaster Assistance and the USGS/USAID VDAP mobilizes at the request of foreign governments of affected countries to assist foreign colleagues monitor, assess, and forecast volcanic hazard activity.
Earthquakes  Photograph credit: Rob Witter, U.S. Geological Survey.	• **Agencies:** FEMA, NIST, National Science Foundation (NSF), USGS, Federal Highway Administration (FHWA) • **Responsibility:** Agency-led reconnaissance teams conduct a general survey of the consequences from the earthquake, document initial observations from the earthquake, and assess the need for followup research activities based on identified topics. In specific earthquakes, the National Earthquake Hazard Reduction Program (NEHRP) agencies will engage in a formal post-earthquake investigation as laid out in the NEHRP plan (Holzer and others, 2003). When transportation infrastructure is involved, the FHWA and its State partners are engaged in damage assessment and reconnaissance. • **Who:** Agencies of the NEHRP (listed above), other agencies as appropriate, and their partners. • **How:** USGS Circular 1242 (Holzer and others, 2003) was developed to outline the official response of NEHRP. NEHRP agencies may deploy their own reconnaissance teams or may support external teams to conduct targeted assessments of geological, geotechnical, and structural impacts. In recent earthquakes, the USGS and FEMA have supported parts of this plan, primarily to support the Earthquake Engineering Research Institute (EERI) to host technical clearinghouses and coordination calls to share information across reconnaissance teams from multiple sectors.
Infrastructure Damage  Photograph credit: Public domain.	• **Agencies:** FEMA/NIST, FHWA • **Responsibility:** FEMA Mitigation Assessment Teams (MATs; FEMA, 2020b) and NIST teams operating under the National Construction Safety Team Act (NCST) deploy to evaluate how buildings have performed after natural and technological hazards. MATs and NIST NCST teams conduct field investigations and make recommendations for mitigation. The findings of these teams can influence immediate rebuilding strategies, as well as longer-term hazard characterization and modelling, mitigation, and prevention activities. FHWA conducts similar activities when damages involve bridges and other highway transportation infrastructure. • **Who:** MATs are composed of Federal, State, local, and private sector experts; NIST NCST teams are composed of engineers and researchers in necessary fields; FHWA teams are composed of engineers and researchers with transportation expertise.

Example Federal Science and Technology Advice Units—Continued	
Issue Addressed	**Responsibilities and Agencies**
Infrastructure Damage—Continued	• **How:** Because NIST and FEMA post-disaster authorities are complementary, these agencies collaborate closely during field investigations. Due to differing priorities, FEMA MATs conclude evaluations within months, whereas NIST NCST investigations can take 3–5 years. FEMA investigations focus on immediate rebuilding efforts, whereas NIST investigations focus on longer-term changes to building codes, standards, and practices that can mitigate risk of building failure and loss of life in the future. FHWA teams closely parallel the work performed by NIST NCST but are more narrowly focused on bridges, highway structures, and their facilities, and have the goal of learning from events to improve building codes, standards, and practices.
All Hazards  Photograph credit: National Aeronautics and Space Administration.	• **Agencies:** NASA • **Responsibility:** Providing relevant information or data during a disaster. • **Who:** The coordination team comprises a headquarters-based group of emergency managers and GIS specialists, as well as disaster coordinators located in six NASA Science Centers across the United States. • **How:** Each Science Center has one or more assigned disaster coordinators who also work on the disaster coordinators team during disaster response situations. Each coordinator acts as a science advisor, specializing in particular hazards, to contribute relevant information or data during a disaster. Fostering widespread relationships within individual NASA Centers and in relevant fields is critical; therefore, the coordination team also liaises across U.S. Government agencies and other disaster relief organizations to ensure the provision of expert knowledge on Earth-observing data and access.

1.4.3 Coordinating S&T Beyond the National Response Framework

1.4.3.1 Formal Interagency Coordinating Bodies

Multiple inter- and intra-agency coordinating bodies exist to organize and direct S&T information during response. Several formal, high-level coordinating bodies have been formed across Federal S&T agencies to ensure that S&T assets and investments are coordinated, that S&T activities address national needs, and that S&T findings and capabilities are put to use for the good of the Nation. Although these coordinating bodies are not prescriptive, they can help diminish the duplication of effort and improve information sharing across organizations. Two were created by the OSTP; the others were created by congressional mandate. These entities often convene coordination meetings when disasters unfold to ensure awareness of relevant assets and data-collection efforts, and to discuss unmet needs related to science for decision support or for rapid-response research.

Subcommittee on Resilience Science & Technology

In support of the White House OSTP, the National Science and Technology Council (NSTC) maintains a standing Subcommittee on Resilience Science & Technology, established in 2019. The subcommittee supports the formulation and implementation of the Federal Government's roles in resilience S&T and research and development (R&D); facilitates mainstreaming resilience R&D and S&T innovations within systems, infrastructure, and organizations; and coordinates Federal resilience R&D responsibilities as called for in Federal policy, including risk management and exercising National Essential Functions.

Science for Disaster Reduction (SDR) Interagency Coordination Group

In support of the OSTP, in 1988, the NSTC chartered the Subcommittee on Disaster Reduction (SDR) where agencies that either produce or use disaster-related Federal S&T products coordinated activities, shared products and breakthroughs, identified needs and priorities, and developed policy for effective disaster risk reduction as appropriate.

When disaster events occurred, the SDR supported the OSTP's advice to the Executive Office of the President and facilitated cross-agency information sharing to support situational awareness and decision making at various levels. In 2019, the Subcommittee for Disaster Reduction became the Science for Disaster Reduction interagency coordination group. Though no longer an NSTC entity, SDR continues to carry out these functions on an interagency level.

Office of the Federal Coordinator for Meteorology (OFCM)

The OFCM was established in 1964 within the DOC. The purpose of the interagency body is to coordinate meteorological activities. A service organization, the OFCM allows for the exchange of information, plans, and concerns among the Federal Weather Enterprise agencies. During an event, the OFCM coordinates wind and water data collection and documentation. It also provides a view of interagency Federal weather efforts to support decisions at executive leadership levels. A working group within the OFCM is specifically focused on disaster impact assessments and plans.

National Earthquake Hazard Reduction Program (NEHRP)

Established by Congress in 1977 as a part of the Earthquake Hazards Reduction Act (42 U.S.C. ch. 86 § 7701 et seq.), NEHRP is the Federal Government's coordinated, long-term, nationwide program to reduce risks to life and property that result from earthquakes. NEHRP develops practices for earthquake loss reduction and policies for their implementation; improves techniques to reduce earthquake vulnerabilities of facilities and systems; advances identification and risk assessment methods of earthquake hazards and improves the understanding of earthquakes and their effects. The Federal agencies involved in NEHRP are FEMA, NIST, NSF, and USGS. NEHRP has an advisory committee consisting of stakeholder community representatives, as well as members from academia and the private with backgrounds in engineering, geology, social sciences, public health, and emergency management. The USGS is the lead agency for post-earthquake investigations with responsibility to initiate coordination calls and assess the need for a NEHRP-level reconnaissance mission within 24 hours of a significant earthquake in the United States.

National Windstorm Impact Reduction Program Office (NWIRP)

NWIRP was established by Congress to reduce losses of life and property from windstorms. The group is meant to coordinate across the Federal Government as well as with State and local governments, academia, and the private sector. This group seeks to improve the understanding of windstorms and their effects, as well as develop and encourage the implementation of mitigation strategies. NWIRP is made up of four Federal agencies: FEMA, NOAA, NSF, and NIST. NIST is designated by Congress as the lead agency for NWIRP.

After an event, the NWIRP lead agency is responsible for coordinating "all Federal post-windstorm investigations, to the extent practicable" (NIST, 2019b). To do this, the NWIRP lead agency identifies opportunities and unmet coordination needs and implements a post-windstorm investigation coordination plan, drawing on existing resources and coordinating mechanisms (NIST, 2019b). The NWIRP lead agency is not required to be physically present at each investigation but is required to play a role in all investigations (NWIRP Reauthorization of 2015, Public Law 114–52).

1.4.3.2 Coordination Calls

As threatening hazards approach and disasters unfold, there is a pressing need for the best-available information for situational awareness and decision support. In addition, S&T communities begin to anticipate the kinds of observations they will need to better understand the event. Formal and informal coordination calls help to establish a common operating picture, which enables situational awareness for emergency managers. Coordination calls can also help Federal S&T agencies coordinate and avoid duplication of effort. These mechanisms are low cost, effective, and nimble.

Example Coordination Calls

Topic	Participants	Activities and Information Exhanged
Windstorm Working Group Calls	Program managers, engineers, transportation specialists, meteorologists, and other relevant experts from FEMA, NIST, NSF, NOAA, HUD, USACE, FHWA, OSTP, NASA.	• Coordinate sharing of post-windstorm findings and other information, including the potential for future research.
NEHRP Coordination Calls	FEMA, NIST, NSF, USGS, and various Federal, State, and academic partners.	• Assess need for a mission. • Exchange information regarding the event.
Interagency Calls on Remote Sensing and Geospatial Assets	Geospatial and remote-sensing experts from across the interagency who provide imagery and information for situational awareness and decision making in their agencies.	• Available products. • Requests for custom products. • Long- and short-term needs.
USGS Storm Response Team	The team is composed of scientists, managers, and technical specialists from all levels of the USGS and, at times, partner agencies. Since 2006, the USGS Storm Response Team has been used in response to severe coastal and inland weather events likely to result in major riverine or coastal flooding, severe wind damage and erosion, ecosystem distress, or threats to life, property, and ecosystems over a wide area to rapidly provide information needed by science and safety decision makers and coordinate ongoing research.	• Coordinate and support field response teams that place sensors and other equipment to provide hydrologic and geographic analysis, analysis of landscape changes, ecological impacts, contaminants, and environmental health.
HHS Disaster Leadership Group	Assistant Secretaries and subject-matter experts from across HHS.	• Scientific background relevant to the current disaster. • New and ongoing research to inform decision making. • Identify and address policy questions.

Example Coordination Calls		
Topic	**Participants**	**Activities and Information Exhanged**
Health Disaster Researcher Engagement	Ad-hoc agency-led efforts by NIH, in partnership with NSF and other agencies, to help coordinate scientists performing disaster research responses in the impacted areas and communities.	• Current and planned research both short and longer-term. • Current and future research needs. • Opportunities for funding, coordination and collaboration, and so on. • Disaster impacts on the research community.
Silver Jackets Collaboration on Flood Risk and Response	States, Federal agencies, Tribes, and local agencies in the areas of hazard mitigation, emergency management, floodplain management, natural resources, or conservation.	• Collaboratively solve state-prioritized issues and implement or recommend solutions. • Improve processes, and identify and resolve gaps and counteractive programs. • Leverage and optimize resources. • Improve and increase flood risk communication.

1.4.4 Funding S&T for Response: Pre-Scripted Mission Assignments and Mission Assignments

Funding and authorities for S&T support need to be in place to allow that work to proceed. In major disasters, activation of authorities and resources for S&T activities is generally accomplished through FEMA task orders, called Mission Assignments (MAs; FEMA, 2020a). When an affected State or territory has a need for Federal services in a federally declared disaster or emergency, FEMA "assigns the mission." MAs allow the appropriate Federal agency to deploy available personnel and equipment to the event when needed to expedite an effective response.

For commonly needed response capabilities, particularly in frequently occurring types of disasters, FEMA has prepared a set of Pre-Scripted Mission Assignments (PSMAs) that are easily adapted and rapidly executed. Though most of these PSMAs involve response-specific needs (for example, providing additional law enforcement or basic supplies to affected areas), they can also include S&T capabilities. FEMA can also mission assign agencies to provide S&T assistance during disasters that may require unique interventions, even if a PSMA is not in place. MAs can lead to PSMAs. An MA can identify a gap or a need in response and allow agencies to develop and demonstrate their capabilities. This scoping process can then lead to the development of a PSMA that can be used in future responses.[8]

Below are some examples of PSMAs and non-scripted MAs that have enabled the use of S&T in disaster response. A full list of S&T-related PSMAs can be found in annex 4.

[8]It is important to note that Mission Assignment-funded work is beyond the scope of regular appropriated activities that is needed during extreme events to inform and aid in response and mitigation efforts.

Example Mission Assignment (MA)
• In 2018, the USGS was mission assigned under ESF 5, information and planning, to provide technical assistance in increasing the understanding of risk and threat to populated areas and energy generation sites posed by lava during the eruption of Kilauea volcano in Hawaii. Additionally, the USGS was mission assigned to provide 24/7 situational awareness video and scientific interpretation of the eruption with UAS.

Example Pre-Scripted Mission Assignments (PSMA)
• EPA: technical analysis of oil and hazardous material releases.
• DOI: subject-matter expertise on archeology, historic environments, and museum collections.
• Department of Energy: expertise on atmospheric releases of radiological, chemical, biological, and hazardous natural materials.
• USGS: subject-matter expertise and data on flood-water heights, landslides, and earthquakes.
• NOAA: expertise on marine debris, hydrographic surveying, aerial imagery, oil and chemical spills, geodetic surveys, hurricanes, and extreme weather.
• National Geospatial-Intelligence Agency (NGA): geospatial analysts, as well as geospatial intelligence during a disaster.
• HHS: scientific experts or consultants, and hazard identification and control measures for environmental health issues.
• NIST: wind-swath mapping following hurricanes to estimate damage, debris, as well as economic and social losses.

1.4.5 Funding S&T for Response: “Ordering” S&T Experts to Incidents

During an event, incident commanders and emergency coordinating staff need a combination of technical information, ranging from weather prediction to subject-matter expertise on diseases or toxic substances. Ensuring that the correct S&T expertise is available to EM staff at the right time requires the ability to “order” expertise and attach it to appropriate incident funding.

As with other positions within incident management teams, S&T experts selected for these support positions need to meet minimum requirements. This may include completing appropriate task books to ensure that they have the proper training and experience. Typically, these experts have been vetted for education, training, skills, knowledge, and physical fitness. These qualifications are laid out in position qualification guides like FEMA’s National Qualification System, the National Wildfire Coordinating Group’s NIMS Wildland Fire Position Qualifications (National Wildfire Coordinating Group, 2020b), or the DOI’s Incident Position Qualification Guide (DOI, 2018). NOAA’s IMETs are one example of qualified and trained experts who can be ordered to an incident to provide weather briefings and forecasts to incident command. Within the Incident Position Qualification Guide, dozens of S&T and support positions are widely used, such as hydrologist and wildlife veterinary technician.

1.5 Lessons Learned

One of the universal challenges of hazard response is ensuring that “lessons learned” do not become “lessons forgotten” (Birkland, 2009). Common post-response and post-exercise activities include post-event debriefing sessions (hot-washes) or after-action reviews to identify what worked well and what needs improvement. Although this reflection process is a key part of the hazard response cycle, it is important for institutions to routinely revisit these documents to ensure improvement.

Many agencies across the Federal Government involved in S&T during response already have corrective actions programs to improve their ability to do necessary science while also supplying key stakeholders with needed information when needed. NOAA’s NWS performs Service Assessments to evaluate the agency’s performance after significant events. Teams consisting of NWS and non-NWS representatives generate a report that considers how useful NWS products and services were for a given event and makes recommendations as to how to improve in the future. NOAA’s National

Ocean Service is subject to similar reviews. The U.S. Committee on the Marine Transportation System, a Federal interagency coordinating committee, includes assessments of the marine transportation system after hurricanes and determines tools and processes to improve resilience. Since 2016, the USGS has developed an After-Action Review process that empowers scientists and science-support staff involved in disaster responses to reflect on what went well, what did not, and how to improve in the future. Recommendations put forward by these After-Action Reviews are tracked quarterly to ensure that they are achieved in a timely manner.

Section 2: Conducting Research in Disasters

2.1 Why Research is Important

The first precept in disaster response is to prioritize safety and the protection of property: save lives, and protect homes, businesses, and critical infrastructure. This principle needs to be recognized and respected across all sectors of the Nation's preparedness and response communities, including S&T. This said, it is often possible and important to undertake timely scientific investigations in disaster settings. Scientists and engineers can provide decision makers with critical insights that can enable a more effective response, protect first responders, limit damage, and (or) improve mitigation.

Studying disasters and their potential cascading consequences can ultimately help improve the response to future events through mitigation, prevention, and strategic planning. Disasters offer unique opportunities to understand the impacts of certain hazards on human health and safety, as well as societally important assets (for example, critical infrastructure, residential and commercial buildings, sensitive habitat, historic structures, and recreation areas). For example, collecting ground-based data following an earthquake allows scientists to deliver aftershock forecasts that provide important situational awareness for responders and incident command. Disaster-relevant data are often perishable, meaning that they will no longer be available or relevant if collected weeks or months following an event. Collecting perishable data necessitates a rapid S&T response, requiring scientists, engineers, and emergency responders to work hand-in-hand.

Oil spill. Photograph credit: National Institutes of Health.

Not all research performed during or after a disaster will provide immediate information to aid in response. There are many situations where research needs to be conducted proximal to disasters to gain insight that can be used to prevent or mitigate damage in future events or improve future response. In some cases, research, or at least baseline data gathering (for example, human and environmental health baseline data, or damage to structures before repairs begin), must be done quickly before conditions change and key insights are lost (Lurie and others, 2013). In other cases, such as in convergence research, interdisciplinary team building as well as problem and solution identification takes time, resources, and cross-boundary collaborations (Peek and others, 2020).

Without research during, and directly after disasters, the response community will continue to have data gaps that will lead to negative impacts resulting from unevaluated or untested mitigation strategies, potentially increasing harm to exposed populations and societal assets, and slowing recovery timeframes. This section of the report outlines mechanisms that can enable S&T research during disasters, guidelines that researchers should follow when in disaster zones, and ways to continue to improve research during disasters. Each section identifies one or more "challenges" aimed at the S&T community. These challenges are intended to highlight areas of needed policy change, inspire culture shifts, and spark novel approaches to conducting research during response.

2.2 Enabling Research During Disaster Response

Disaster events and their cascading consequences are often unanticipated or occur with little notice. As a result, it is often a challenge for researchers to find funds to quickly deploy to these events to collect critical baseline data or perishable data that can only be collected during or immediately after a disaster. It can also be a challenge for scientists to obtain IRB approvals for research involving human subjects on short notice (Packenham and others, 2017). Because approaches are often hurried and uncoordinated, research efforts and approaches typically vary from disaster to disaster, making comparisons between data and lessons learned difficult, if not impossible. Researchers upon whose data critical decisions are based may also open themselves up to issues of liability if those decisions lead to negative outcomes (Institute of Medicine, 2015).

To perform timely research, the following elements are necessary:

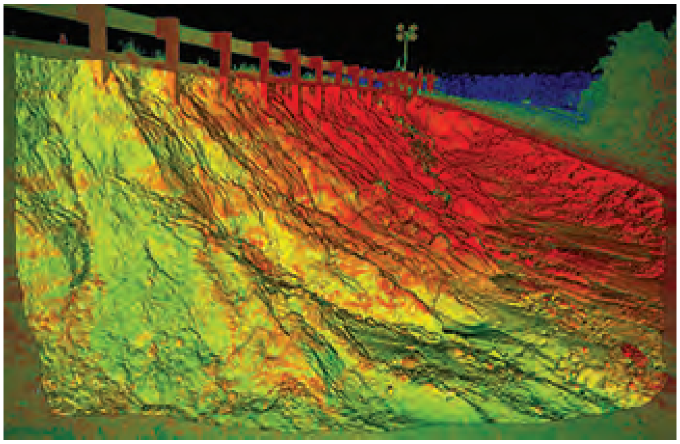
- Coordination among researchers during non-crisis times to develop research processes, protocols, and priorities that can be put into effect when anticipated disasters occur.
- Rapid identification and communication of data gaps and research priorities.
- Mechanisms that allow researchers to rapidly obtain funding.
- A strategy for expediting Office of Management and Budget (OMB) approvals of information collections (for example, surveys and interviews) through the Paperwork Reduction Act (PRA, 44 U.S.C. 3501 et seq.). This may include mechanisms such as umbrella OMB/PRA clearances or expedited/emergency clearances that allow researchers to rapidly implement standardized data collection instruments.
- Processes for timely IRB review and clearance.
- Access to valid and standardized data-collection tools, protocols, and rapid training for researchers, digital volunteers, and citizen scientists (where appropriate).
- Systems and platforms for trans-stakeholder data management, integration, analyses, and dissemination.
- Platforms for rapidly engaging Government agencies, academia, nongovernmental organizations, citizen scientists, volunteers, and communities.
- Integration of data collection and research activities into planning and emergency response frameworks.

2.2.1 Agile Protocols for Research

It is important for researchers to design research protocols for disasters during “blue sky” times to improve efficient S&T response during a disaster. Although each disaster is unique, many important research questions that arise during events can be anticipated (National Biodefense Science Board [NBSB], 2011, p. 12). Pre-planning research questions and identifying known knowledge gaps is important for quickly developing research protocols (NBSB, 2011, p. 4). A few specific ideas for creating agile research protocols are below.

Challenge: Design research protocols for disasters <u>before</u> disaster strikes.

- “Pre-identify” high-priority research protocols to ensure that data of mutual interest are collected during a disaster.
- Develop standardized workflows, or pre-developed and pre-positioned repositories of tools, resources, and guidance to accelerate the transfer of S&T information.
- Collaboratively develop playbooks that enable researchers and responders to understand what will happen and when it will happen during a disaster to limit surprises or unforeseen requests.
- Examples:
    - Clinical researchers who responded to the Ebola epidemic in 2016 suggest creating a clinical



A three-dimensional terrestrial lidar scan of the Percy Quin Mississippi State Park Dam in McComb, Mississippi, taken as apart of USGS efforts to map impacts by Hurricane Isaac. Image credit: Toby Minear, U.S. Geological Survey.

research database that would include template documents for clinical trial design, as well as contractual agreements including data sharing, logistical checklists, and post-trial expectations. These templates would allow scientists to avoid starting at zero during each response (NASEM, 2017, p. 182).

- The NIH DR2 Program (https://dr2.nlm.nih.gov/) has created a repository of over 350 publicly available data-collection instruments, guidance, training materials, and protocols to help health researchers speed up the design and field implementation of research. The repository includes a novel NIH IRB pre-reviewed generic study protocol, Rapid Acquisition of Pre- and Post-Incident Disaster Data (RAPIDD), to allow researchers to minimize the time needed before beginning data collection during or immediately after disasters. The DR2 also has training materials for research responders and hosts workshops to improve the capacity of research among numerous multidisciplinary stakeholders.
- EERI developed a field guide (EERI, 1996) that outlines existing knowledge gaps across numerous fields that can guide the development of future research protocols.
- The NSF-funded CONVERGE facility has developed a series of free online training modules and extreme events check sheets that are designed to help quickly background early career researchers and others new to the field on its history, methods, ethics, and long-standing findings (CONVERGE, 2020d).

Challenge: Ensure that communities are a part of research design before disasters.

Pre-positioned research protocols can be improved by collaboration between researchers and appropriate community leaders in hazard-prone areas. Each community has unique informational needs and concerns in a disaster and thus should be engaged in study design. To this end, ongoing public health and community-engaged research efforts can help to serve as platforms for better engaging communities within the context of the disaster responses. For example, academic researchers investigating communities living near Superfund sites in the Houston area were quickly able to reconnect with their community partners after Hurricane Harvey to implement timely investigations of interest to the community, academia, and public health officials (Horney and others, 2018).

2.2.2 Rapid Funding, Equipment Procurement, and IRB Approval

Challenge: Provide scientists with rapid funding and equipment for research.

Several mechanisms exist to fund Federal scientists' and engineers' work during or after disasters. As mentioned in section 1.4.4, MAs from FEMA can enable rapid disaster data collection. After a disaster declaration, agencies that have performed S&T duties beyond the scope of those mandated by appropriated funds may receive reimbursement if supplemental funding is approved by Congress. Supplemental funding can also support the rebuilding of S&T capabilities or monitoring networks that were damaged by the event, strengthen those capabilities for future events, or both.

For academic researchers, some institutions have created rapid funding mechanisms to get scientists and engineers into the field quickly:

- The NSF currently supports seven Extreme Events Reconnaissance and Research (EER) networks (CONVERGE, 2020c) focused on geotechnical engineering, social sciences, structural engineering, nearshore research, operations and systems engineering, sustainable material management, and interdisciplinary research. This EER ecosystem provides funding to move researchers and research teams into the field after a disaster in a coordinated way while encouraging cross-disciplinary information sharing and interdisciplinary integration.
- The NSF offers Rapid Response Research (RAPID) grants (NSF, 2020) that can fund proposed projects quickly, within weeks or even days, if critical data is perishable and would disappear or erode if not gathered immediately. NSF rapid-response awards have supported physical, engineering, and social science research in all sorts of disasters for decades.
- The NIH has Time-Sensitive R-21 grants (National Institute of Environmental Health Sciences [NIEHS], 2020a) that can award funding for health-related research in about 3 months. These grants have been used to support data collection in response to the Zika outbreak, hurricanes, wildfires, and other emergencies.
- The Natural Hazards Center Quick Response Research Grant Program (Natural Hazards Center, 2020), supported by NSF, provides researchers with

funds and training for data collection after disasters. The program focuses on social science and multidisciplinary collaboration. New or unique areas of study that require the collection of perishable data are prioritized in the funding process.

- Although they do not dispense funds for research, the NSF-funded Natural Hazards Engineering Research Infrastructure Natural Hazards Reconnaissance Facility (referred to as the “RAPID Facility”) can provide researchers with equipment, software, and support services needed to collect, process, and analyze perishable data during natural hazard events.

Challenge: Provide mechanisms to provide rapid IRB approval for human-subjects-related research during disasters.

To conduct research involving human subjects, researchers are legally required to obtain approval from an IRB or Human Subjects Protections Office (45 CFR 46). These approvals are important because they ensure that human subjects are treated in a safe and ethical fashion. However, research protocols can sometimes take months to gain IRB approval. Several agencies have set precedent for expediting the IRB approval process:

- The NIH RAPIDD Research Protocol (NEIHS, 2015) developed by the NIH DR2 Program has been prereviewed by the NIEHS IRB to allow for timely final approval provided that the protocol is only used for a single disaster activity, that any amendments undergo IRB review, and that investigators report back to the IRB regarding any study activities that affect the safety of research subjects. The NIH has also made progress toward streamlining the IRB process by introducing a single IRB for multisite research. Currently, the NIH DR2 Program is spearheading efforts among Federal agencies to improve processes, training, and guidance for rapid IRB reviews and the availability of IRB prereviewed protocols. Of note, the NIH RAPIDD Research Protocol has been adopted by several universities and has been used by academic researchers to quickly get into the field within 2 weeks for time-critical data collection. However, to enable rapid research during disasters, other Federal institutions should work to create similar pre-approved protocols that researchers can draw upon when needed.

NIST social scientist Erica Kuligowski (left) interviews a tornado survivor in Joplin, Missouri, in 2011. Photograph credit: National Institute of Standards and Technology.

- The Centers for Disease Control and Prevention (CDC) has similar IRB procedures to those at NIH. The CDC IRB has an emergency procedure for submitting protocols for urgent review. It is possible to get IRB approval in about 5 days. The current human subjects Common Rule (45 CFR 46) allows for “public health surveillance” to be deemed not subject to IRB review. Such a protocol would still need to be entered and approved through a CDC study tracking system declaring that it is public health surveillance. After that point, the public health surveillance protocol no longer needs IRB oversight. This dispensation is applicable whether the protocol is considered an emergency activity or not. The CDC’s National Institute for Occupational Safety and Health (NIOSH) Disaster Science Responder Research Program (NIOSH, 2020) is establishing a disaster science IRB to provide rapid review of research. NIOSH has been developing a generic protocol accordingly; however, it has not yet been finalized.
- NIST has also operated within an IRB Authorization Agreement when collaborating with other institutions in post-disaster research. This increases efficiency in collaboration and ensures compliance. The NIST Community Resilience Center of Excellence (NIST, 2018), led by Colorado State University, includes 12 institutions and is funded as a collaborative grant from NIST. The Colorado State University IRB serves as the IRB of record for the field-based components of the research with the other institutions and NIST as collaborators. The research protocol was approved as an umbrella study that would support rapid response to disaster events. As such, the research team submits an amendment for specific disaster research events that would be reviewed and approved within days of an event.

This mechanism has been in place since 2016 and has enabled successful research in response to several disasters.

Challenge: Design and implement a strategy for OMB approvals of information collections (for example, surveys and interviews) through the Paperwork Reduction Act (PRA, 44 U.S.C. 3501 et seq.) that includes mechanisms such as umbrella OMB/PRA clearances or expedited/emergency clearances that allow researchers to rapidly implement standardized data-collection instruments.

An effective strategy for NIST has been to develop a “generic clearance” for disaster and community resilience research topics. It should be noted that although the review time is shorter for information collections under a generic clearance, each still needs to be individually reviewed by OMB for appropriate approval. This mechanism allows for the clearance to be obtained in nondisaster times and includes anticipated data to be collected and an estimate of the time required to do so effectively. The specific instances of data collection then require a shorter submission process that avoids the lengthy time associated with the standard initial package requirements (for example, 60-day Federal Register Notice).

2.3 Respectful and Effective Engagement During Disasters

Areas struck by major disasters may lack basic sanitation, electricity, lodging, food, and water. Communities and (or) disaster victims may be traumatized, have experienced great loss, feel powerless, and be struggling to meet basic needs. Access to disaster zones is often restricted to prevent further injury or illness and to protect victims and their property.

Recognizing this austere working environment, scientists and engineers should be prepared to enter the unique physical, logistical, and political landscape of an affected area when considering pursuing research during or immediately after disasters. Preparation includes being ready to be self-sufficient, knowledge of the Federal response framework and ICS, training for the health and safety hazards and stressful situations, understanding best practices for community engagement, and working with emergency managers and responders to ensure that S&T efforts do not interfere with response activities or divert important resources. In addition, researchers should enter disaster-struck environments respectfully, humbly, and with the knowledge and agreement of EM officials and (or) affected communities (Gaillard and Peek, 2019).

Despite the need for substantial preparation, there is little information and guidance for scientists and engineers working in disaster zones (Wilson and others, 2015). One example of guiding principles for engagement comes from NOAA’s NWS, where the following are attributes identified as important for those considering a S&T advisor role:

- Ambition, or a desire to provide the best possible assistance during a response.
- Dedication, or a willingness to provide 24/7 support.
- Versatility, or an ability to provide support across multiple disciplines for all hazards.
- Technical flexibility, or a capacity for working with evolving technology.
- Optimism, or the belief that NOAA can have a positive impact on response planning and operations through sound and reliable science.
- Credibility, or the ability to build trust and confidence in NOAA through professionalism with our clients and stakeholders.
- Proactivity, or the ability to anticipate the needs of our customers and provide solutions early.
- Stamina, or an ability to sustain performance in an environment that can be mentally and (or) physically demanding because of long hours and (or) living in outdoor conditions (especially for onsite work).

Though these attributes were written for NOAA employees, they are broadly applicable across institutions that can provide S&T capabilities during different disasters. Institutions should consider developing their own protocols or guidelines for supporting and preparing scientists and engineers working in these unusual and often stressful or potentially dangerous environments. For example, NIEHS provides a researcher deployment guide that provides researchers with (1) pre-deployment information covering a range of topics from packing, family matters, and what to expect in the field to physical and mental preparedness; (2) deployment information regarding ICS, arrival instructions, data management, and protection; and (3) postdeployment resources for mental health support (NIEHS 2017). The following subsections offer examples for improving safe, respectful, and effective disaster research.

2.3.1 Accessing Research Sites Respectfully

Challenge: Ensure that researchers seeking to enter disaster areas to perform research do so respectfully.

Researchers seeking to enter disaster zones should be respectful of the communities, individuals, and responders impacted by these events. Researchers should recognize the primacy and rights of those immediately affected by the crisis (Colwell and Machlis, 2019, p. 15). Where possible, community members and individuals should be integrated as full partners in scientific investigations after the events that affected them (Wilson and others, 2015; NBSB, 2011, p. 5). Communities should be able to propose research questions that can address their concerns after disasters, where possible and feasible. These groups should also be a part of data collection and study design, if feasible and of interest. Incorporating communities into research protocols can empower them in the wake of devastating events rather than further marginalizing them as research subjects or bystanders. Incorporating communities into research can enhance the breadth and depth of the findings or incorporate questions that outside researchers would never think to ask.

Considerations for Including Communities in Research After Disasters

Flooding in New Orleans from Hurricane Katrina, 2005. Photograph credit: Jocelyn Augustino, Federal Emergency Management Agency; public domain.

Important factors need to be considered when working to incorporate communities into research design and practice, including:

- Local researchers and scientists should be partners (if not leaders) of research design and implementation.
- Establishing an equitable and respectful relationship with community groups, particularly in areas where local researchers may face structural inequities and disadvantages in their careers as scientists is critical.
- Communities are not monolithic. Finding a single person or group to represent “the community” is often impossible. Thus, it may be better to find a group of individuals who can inform the work at hand.
- Communities engaged in disaster response or recovery may not have the time or the attention for research design as they deal with monumental challenges to their everyday existence.
- Engagement with communities can result in years- to decades-long relationships and should not be entered into without long-term engagement in mind.

Challenge: Ensure that scientists and engineers performing research in disaster-affected areas do so safely.

Researchers should be judicious about requesting access for research, restricting themselves to data collection that can only be performed during or directly after a disaster. Access should be requested not only for the researchers themselves but also for equipment and data-collection platforms such as UASs. To avoid becoming victims in need of rescue themselves, researchers should coordinate with incident commanders to gain access to areas controlled for safety and security or to allow response operations to proceed unhindered. Often, working through the ICS is the best way to start this coordination (see fig. 1 in section 1.4.2). If necessary, researchers should be able to demonstrate that they are prepared to conduct research in areas where there may be significant logistical challenges because of damaged infrastructure and in such a way that will not interfere or place undue burdens or risk to the response efforts that are ongoing.

Scientists and engineers seeking to enter disaster areas to perform research should prioritize safety and have appropriate training for anticipated hazards as well as the use of personal protective equipment (PPE), including the availability of PPE for their teams. Finally—and importantly—researchers, similar to other response workers, should consider having training and support in dealing with the stress and emotionally challenging elements of disaster situations.

Example of How to Safely Operate in the Field: National Institute of Standards and Technology

NIST staff in the field after Hurricane Michael. Photograph credit: National Institute of Standards and Technology.

NIST personnel operating in the field must be alert to the potential hazards present in the immediate environment and take the appropriate steps to mitigate or eliminate the risk posed by a hazard. Here are some steps that are taken to ensure personnel safety:

- **Hazard Review:** A first-level hazard review for the NIST disaster field activities is updated and reviewed regularly by a panel of experts to identify common hazards (for example, downed power lines, damaged structures, debris, heat stress, violence, and so on) that are encountered during field work and associated mitigation controls (for example, PPE, training courses, first-aid kits, and so on).
- **Defined Protocols:** NIST safety standard operating procedure (SOP) one-pagers are tailored for each deployment type and include required training, supplies, and PPE, as well as safety precautions associated with expected risks by hazard type (for example, wildland-urban interface fires, building fires, hurricanes, floods, windstorms, earthquakes, and construction failures). The applicable one-pager is reviewed and discussed with the entire team during a safety briefing at NIST before deployment.
- **Practice:** Table-top exercises, simulating typical NIST disaster field activities, were developed to review existing safety protocols, identify gaps in the safety protocols, and recommend potential changes to the first-level hazard review.
- **Continuous Assessment:** During the deployment, NIST personnel meet before each day's field activities to discuss the technical activities for the day, to discuss the anticipated hazards, to review the safety SOP, to inventory the safety-related equipment, and to decide upon the time and location the team will reconvene throughout the day.

2.3.2 Build Relationships and Familiarity in Advance of Disasters

Challenge: Build trusting relationships between researchers and emergency responders before disasters.

The NPS and the NIMS recognize that all emergencies are local, and Federal response efforts follow and support local, regional, and State response. Every effort is made to ensure that disasters are managed at the lowest possible geographical, organizational, and jurisdictional level. It is also intended, however, that Federal S&T capabilities be brought to bear to assist in events at any level when they can improve disaster outcomes.

In the throes of a crisis, State, local, Tribal, and territorial EM officials often reach out for advice and assistance to those Federal officials with whom they have pre-existing working relationships. Often, these are State emergency managers, FEMA regional officers, and (or) regional officers from other agencies who, in turn, have relationships or familiarity with the capabilities of Federal S&T personnel and offices. Establishing trust, as well as administrative protocols to effectively incorporate S&T into disaster response in a timely fashion in advance, is key to providing responders with needed information for decision making and situational awareness as quickly as possible. Because of this inherent reliance on personal networks during a disaster, researchers and emergency responders need to build trusting relationships *before* these events occur to effectively conduct research and use technical information in disaster-affected areas. These relationships can exist at multiple levels, from the local researcher and local emergency responder up through the wider response system and S&T policy-level discussion promoted by this document.

Relationships can be fortified through multiple mechanisms, such as:

- Routine interagency and (or) community meetings (for example, local and regional task forces). Examples:
    - Subcommittees of the interagency National Tsunami Hazard Mitigation Program, where scientists and practitioners meet on an annual basis to exchange information.
    - On a more informal level, in the Pacific Northwest, a group meets several times per year for networking events, where scientists and responders from across the region meet at a local restaurant or pub to share ideas, resources, and contacts.
- Incorporating undergraduate or graduate researchers into EM processes like pre-event or mitigation planning. Interns can offer writing, GIS, and other support. These activities can help forge lasting connections between the EM and academic communities and can help researchers gain a deep understanding of EM terms, structures, and protocols before disaster strikes.

Training exercises. During exercises, emergency responders can establish familiarity with S&T products, information, and tools, as well as connect with subject-matter experts who may become on-call resources when disaster strikes. In turn, scientists and engineers can build relationships, learn about emergency response protocols, and have a front row seat to how S&T information is—or sometimes is not—used during response (for example, Reddy and others, 2016).

Example Training Exercises

Photograph credit: Steve Martarano, U.S. Fish and Wildlife Service.

In 2015 and 2016 the U.S. Military and North Atlantic Treaty Organization allies included biogeochemists with expertise in oil spills in an exercise that involved a fictional conflict between two Scandinavian nations (Reddy and others, 2016). These scientists were asked to help the military understand the potential consequences of the deliberate sinking of refueling ships in an economically important fishery. This information allowed the U.S. Military and North Atlantic Treaty Organization forces to understand the ideal conditions to sink a refueling ship to mitigate environmental damage. Establishing trusting relationships and known points of contact during exercises can allow scientists to intervene quickly and effectively in times of crisis. For example, if this scenario were to ever become reality, this exchange may mitigate the pollution of important fisheries and ecosystems.

Example Training Exercises—Continued

Photograph credit: National Institute of Environmental Health Sciences.

The NIEHS DR2 Program has organized four tabletop exercise/workshops (2014, Los Angeles, California; 2015, Houston, Texas; 2017, Boston, Massachusetts; 2019, Tucson, Arizona) to bring together Federal, State, and local scientists and officials, academic researchers, healthcare workers, emergency managers, first responders, industry, and community organizations to work through issues surrounding data collection and research in response to disaster scenarios (NIEHS, 2020b).

For example, the 2015 exercise in Houston simulated the impacts of a hurricane like Katrina, resulting in contaminant spills, flooding, closed roads, power outages, and evacuations. This exercise included over 120 representatives from academia, Government, the local community, industry, and local emergency responders. The exercise sought to determine State and local disaster research capabilities and the ability to prioritize research needs, explore ways to access Federal research resources, as well as existing and potential response and recovery relationships. The exercise identified challenges to be addressed, identified areas where potential partnerships could be forged, and strengthened existing responder-researcher capabilities and relationships. The value of this exercise was showcased in 2017 when Hurricane Harvey hit the Houston area. Local researchers quickly connected with area health officials, emergency managers, and community stakeholders to address issues of concern. NIH in partnership with other Federal agencies held needed teleconferences to help facilitate and coordinate the evolving research collaborations by universities in Texas and from across the United States. Using pre-reviewed IRB protocols and tools from the NIH DR2 website, researchers were able to get into the field within 2 weeks to begin collecting time-critical exposure and health information in coordination with impacted community members and stakeholders (Horney and others, 2019).

Photograph credit: Federal Emergency Management Agency.

Each year FEMA conducts a series of tabletop, functional, and full-scale exercises in partnership with a variety of other Federal agencies, States, local governments, nongovernmental organizations, and private sector partners. The purpose of these exercises is to test and improve the ability for the whole community to respond to a variety of severe events. These exercises help identify gaps and help build discussion of recovery strategies.

In 2019, the “Shaken Fury” exercise focused on a hypothetical magnitude-7.7 earthquake striking an area near Memphis, Tennessee. During the event, subject-matter experts from the USGS, Department of Energy, NIST, NOAA, and NWS interacted with U.S. Northern Command, National Guard Bureau, FEMA, and State and local EM groups. Several scientists embedded in emergency operations centers during the exercise (Department of Homeland Security, 2020).

2.3.3 Familiarity with Emergency Response Frameworks

Challenge: Ensure researchers are aware of emergency response frameworks, terms, and protocols to navigate responses safely and effectively.

Even if researchers cannot engage in training exercises, they should take basic EM training to understand the hierarchy, protocols, and terms necessary to safely and effectively navigate an emergency response. Notably, nonfield deployments can be as stressful as field deployments and may require scientists and engineers to operate within EM SOPs and protocols. No one is exempt from knowing those procedures and understanding the various workplace challenges of working a disaster.

Basic training for researchers deploying to disaster-affected areas needs to cover the appropriate topic for the type of research work being done and the level of direct involvement with a site or the involved responders. FEMA's Emergency Management Institute (https://training.fema.gov/emi.aspx) offers multiple resources in these areas. In other cases, guidance or training may need to be developed by specific institutions or groups to meet their unique needs or requirements. Considerations for training could include the following topics:

- NIMS
- IS 100, 200, 700, 800 (from FEMA's Emergency Management Institute)
- Health and safety, including the mental health aspects of disaster work
- Response infrastructure and reporting chains
- Reporting structure and settings
- Needed equipment, PPE, and supplies
- Logistical and administrative concerns
- Best practices for risk communication and effective community engagement
- Response communication practices including radio etiquette, radio channel use and priority, and satellite and cell communications protocols

2.3.4 Ensure Self-Sufficiency

Challenge: Ensure that scientists and engineers seeking to conduct research in disaster-affected areas are self-sufficient to avoid placing further burdens on supplies, communities, and facilities.

Areas struck by disasters are often inundated with first responders, media, volunteer groups seeking to help with rescue efforts, and curious members of the public. An influx of people in disaster areas can slow or complicate response efforts and place a strain on vital resources. In addition, in large scale disasters like Hurricane Michael in 2018, safe housing, water, fuel, and food become extremely limited in the affected area. To avoid using resources needed by the affected community and to ensure their own safety, researchers should consider coming ready to sustain themselves by bringing their own:

- food and water
- shelter (for example, RVs or tents)—an additional benefit to self-sustaining lodging is eliminating long commuting hours during an already taxing work environment (National Wildfire Coordination Group, 2020a)
- power supplies (for example, solar panels and portable generators with fuel)
- first aid supplies
- PPE

2.4 Communicating Science During Emergency Response

Challenge: Ensure that scientific information is provided to those who need it at the right time and in useful formats during a disaster.

Scientific information is needed by decision makers to quickly address critical issues and make key determinations during events. To provide this information, scientists and engineers involved in event response should be prepared to communicate their findings to nonscientific audiences quickly and in formats that can be understood by lay-audiences. Scientists and engineers should make efforts to make appropriate contacts with incident leadership to understand with whom they should communicate their findings, and in what formats. For example, scientists and engineers may be asked to brief leadership at the beginning of each operational period so that those coming on shift have the most up-to-date common operating picture possible.

During a disaster, S&T information is needed for decision making before a lengthy peer review process.

FEMA Region II hosts the National Hurricane Center (NHC) as part of Readiness Day on April 26, 2018. Photograph credit: K.C. Wilsey, Federal Emergency Management Agency.

Scientists and engineers should be prepared to share their analyses, even if they are not complete. As is frequently expressed by the EM community, “an eighty percent solution is better than none at all.” One way that researchers have been able to share research findings before the publication of their research is by writing blog posts or tweets that summarize the key findings of their research. This approach makes research rapidly accessible and easy to share with the EM community and other stakeholders.

Challenge: Ensure that research and scientific findings are discussed in a credible and respectful way.

Disasters may be fascinating to the scientists who study them, particularly if those events are rare or unusual. Some events may only occur once in a researcher’s lifetime and define entire careers. However, it is important to remember that lives, property, and community well-being may be at stake. Scientists and engineers should make every effort to use a respectful tone when discussing their work with the media, local communities, and public officials. Using the incorrect tone can make it more difficult for scientists and engineers to gain access to potential research sites and create feelings of uneasiness or ill-will toward the research community. Research results should be shared with affected communities regardless of whether the results aid in the immediate response or recovery. Failing to share research findings can be perceived as hiding information from the public or can lead to less qualified individuals sharing potentially incorrect information (Wilson and others, 2015). This respectful engagement avoids perceptions of “hit and run” or extractive models of research. It can also create avenues for sustained researcher-community engagement, open opportunities for community review, and help refine research results and analysis. Such coordination strengthens relationships, messaging, and effectiveness of response and recovery efforts involving affected communities.

Challenge: Develop protocols for addressing conflicting research findings and communicating scientific uncertainty during an event.

Studies with divergent findings may come to light during an event. In these cases, the S&T community must develop pre-incident approaches for addressing conflicting findings and communicating uncertainty to decision makers in such a way that it informs, rather than impedes, evidence-based decision making (Colwell and Machlis, 2019, p. 11). The Intergovernmental Panel on Climate Change’s guidance on communicating uncertainty is one example of how likelihood and confidence can be communicated to decision makers, where relative terms such as “very high,” “high,” “medium,” and “low” are used for summarizing information and consensus (see Mastrandrea and others, 2010). Other examples include rapid assessment of scientific information and uncertainties in response to emergencies. For instance, during the Deepwater Horizon oil spill (2010) and the Ebola (2014) and Zika virus (2015) outbreaks, the NASEM collaborated with HHS to quickly bring together international experts to assess the situation, evaluate available data and research, and make recommendations regarding additional investigations that needed to be pursued to inform decision making (Institute of Medicine, 2010; Institute of Medicine and National Research Council, 2014; NASEM, 2016).

2.5 Sharing and Standardizing Data

To prevent redundancy, sharing data is critical to conducting research during disasters. Standardizing data collection is also very important because it:

- helps responders anticipate data formats and create workflows that make the ingestion of these data seamless during a disaster;
- reduces duplicated efforts; and
- allows comparison of data between different areas during a response, across similar responses, or both.

In a competitive academic environment, sharing data is not always a priority for those mobilizing quickly to conduct research during a response. However, scientists and engineers must favor altruism over competition in their research—collaborating on data collection and sharing resources, data, and equipment as needed (Colwell and Machlis, 2019, p. 15). Although collecting data in a standardized way may feel restrictive or hampering to researchers in the field, it is important to recognize that standardized data collection can often be done alongside innovative data collection.

Challenge: Standardize data collection and analyses during hazard response.

Collecting data in standardized formats is critical to their use during response and can streamline research and response efforts. For example, in May 2019, FEMA's Urban Search and Rescue Branch signed a memorandum of understanding to make ArcGIS' Survey 123 Field App available to support search data collection. Standardizing the collection of geospatial data for urban search and rescue can greatly reduce duplicated efforts, help emergency responders quickly identify areas that have not yet been searched, and quickly relay information back to decision makers as events unfold. In the case of search and rescue, timely sharing of standardized data can save lives. The time it takes to compile and analyze disparate data types and form an operational plan is time lost when searching for disaster victims for whom every minute counts. Along similar lines, the NGA has designed the Mobile Awareness GEOINT Environment (http://ngageoint.github.io/MAGE/), a mobile application that allows first responders and researchers to create geotagged observations in the field and share them instantly during disasters.

Groups like the Environmental Disasters Data Management Group out of the University of New Hampshire have made inroads in this arena by providing guidance on infrastructure design elements to enable rapid data discovery and retrieval by people who need it quickly (University of New Hampshire, 2020).

The NSF-supported CONVERGE facility at the University of Colorado Boulder in partnership with the NSF-funded DesignSafe Cyberinfrastructure at the University of Texas Austin have established a Data Ambassadors program to encourage social and behavioral scientists to publish their data collection protocols and instruments as well as their data (NSF, 2019). This program teaches investigators how to curate their data and metadata and supports publication. The CONVERGE Data Ambassadors, in turn, commit to assist other investigators to publish their research related materials. Not only do investigators receive a permanent Digital Object Identifier for their materials, they also are contributing to building a much larger repository of instruments and data for later reuse (CONVERGE, 2020a).

Challenge: Standardize data collection and analyses across multiple hazard events.

Although difficult, standardized data collection can also be invaluable for comparing information across multiple events. Such comparisons can improve future response efficiency and allow response and research communities to continue to build upon existing information. For example, the NIH DR2 Program has created a repository of questionnaires focusing on differing areas of interest including environmental exposures, mental health and cognitive function, occupational health, social support and resiliency, and other topics across events. These data-collection tools can be tailored as indicated for the specifics of a disaster situation. These efforts are being done in collaboration with the National Library of Medicine's Common Data Elements Repository (https://cde.nlm.nih.gov/home) to help facilitate the use of standardized questions and questionnaires across disaster situations.

More generally, the Harvard Humanitarian Initiative KoBo Toolbox Suite (https://www.kobotoolbox.org/) offers free and open source tools for data collection during humanitarian crises. The suite includes mechanisms to build forms from predetermined question sets, to collect data with mobile devices, and to analyze the data collected. Although not as structured as the DR2, CONVERGE, or KoBo formats, EERI offers guidelines for specific data collection in the field in its field guide (EERI, 1996).

Challenge: Coordinate data collection during response across the research community to minimize redundant efforts.

Coordinating data collection during events across research groups can help minimize the footprint of researchers in the affected area, reduce redundant efforts, facilitate the sharing of information between the S&T and EM communities, and minimize stress on affected populations. Coordinated data collection can also assist emergency managers because information on critical infrastructure, such as roads, runways, and hazardous waste sites, can be consolidated and incorporated into situational awareness briefings for field crews (Warren Mills and others, 2008). Data clearinghouses also provide a historical record for application in future disaster events (Warren Mills and others, 2008). As Tierney (2019, p. 115) observes, "[t]he best way to deal with the threat of unacceptable levels of burdensome research is for research teams to communicate and collaborate voluntarily—for example, by sharing information on the topics they are studying and on the timing of their research activities, or by exploring ways to consolidate data collection and data sharing."

The earthquake science and engineering community exemplifies this type of coordination. Immediately after an earthquake, researchers coordinate data collection and data sharing quickly and comprehensively. Researchers convene to set priorities for survey sites and data collection. Teams are prepared to gather information needed by the earthquake science and engineering community, not just what is of interest for individual scientists and engineers. The data and information gathered are deposited in a single clearinghouse repository9. Beginning with California's Northridge Earthquake in 1994, earthquake clearinghouses have been used as an information source by emergency managers, not just researchers. Using a similar model, immediately after Hurricanes Katrina and Rita, FEMA, and Louisiana State University worked to develop the disaster-based Louisiana State University GIS Clearinghouse Cooperative to collect, organize, share, and archive geospatial data and analyses that could speed response and recovery from the hurricanes that ravaged Louisiana in 2005 (Warren Mills and others, 2008). The medical community also uses clearinghouses for sharing information: the NIH National Library of Medicine, Disaster Information Management Research Center (https://disasterinfo.nlm.nih.gov/) provides access to curated health information resources during disasters or public health emergencies.

Communities affected by disasters are frequently the subject of research seeking to better understand the short- and long-term social and economic effects of the disaster—this information is used for advancing academic research and can be useful for directing aid. However, research that involves human subjects (for example, interviewing and conducting surveys) can lead to additional burden and stress in an already strained population, yielding poor participation and support, as well as anger, frustration, and increased stress. Thus, coordinated research within areas affected by disasters can limit redundancy in data collection and equipment in the affected area. Funding mechanisms like the NSF RAPID program can incentivize coordination between researchers working in similar areas. The NSF-funded coordination networks, such as the Social Science Extreme Events Research and Interdisciplinary Science and Engineering Extreme Events Research (a complete list can be found above in section 2.2.2), are designed to help researchers connect with one another across multiple disciplines, to help define research questions, and to support scientists with ethical guidelines for conducting research during disasters (CONVERGE, 2020c). Federal agencies can continue to foster coordination through strategic funding and multidisciplinary discussions with the extramural research community to foster collaborations, cost-effectiveness of public investments, innovative solutions, and reduced burden on affected communities (Horney and others, 2019).

[9]See the Earthquake Clearinghouse (http://www.eqclearinghouse.org/) for examples of the earthquake data and information repositories.

Challenge: Archive, catalog, and curate data collected during an event to inform future research.

Often, data collected during an event are not archived or catalogued in a consistent manner. Data for a single event may be scattered across multiple institutions with differing levels of access. Data for the same type of disaster event (for example, inland flooding) may be even further scattered across organizations and may be inconsistently accessible, making comparisons across events difficult. To ensure that single-event and longitudinal disaster data are findable, accessible, interoperable, and reusable (Wilkinson and others, 2016) by researchers, it would be best if data for a single event, and (or) a disaster type were archived, cataloged, and curated in a single, widely accessible location. Clearinghouses have helped consolidate data for single events, whereas efforts to handle the collection and storage of data from a single type of disaster have been developing. For example, EERI has increased discoverability of earthquake data for the research community. Geoplatform seeks to collect geospatial data across disasters into a single, accessible clearinghouse. Ideally, research findings based on the data collected during disasters that comes out well after these events have ended would be linked to or deposited in the same location as the data so they can easily be found by future researchers.

This type of cataloging is facilitated by the creation of information clearinghouses. The NIH DR2 Program, the NIST HubZero (Letvin and Pujol, 2013), and the EERI have sought to archive and make information publicly available to help improve timely data collection and research in response to disasters. Similarly, Geoplatform (https://www.geoplatform.gov/category/disasters/), the Federal Government's online portal for geospatial data, has created an archive for past events.

Section 3: Moving Forward

3.1 Relationships are Key

Disaster responses are high-stress, high-stakes, high-intensity situations. Decisions must be made quickly and can have life-or-death consequences. There is little time to make new personal or professional connections or to build trust with new partners. Developing regular interactions between scientists and engineers, Federal, Tribal, and State emergency responders, and local communities before disaster strikes is critical to building trust among these groups. With that trust comes access, fruitful collaboration, and responses improved by S&T input. This report challenges emergency managers to reach out to a scientist or engineer who has expertise in a field that might be helpful during a crisis event. Likewise, scientists and engineers are challenged to reach out to emergency managers who might find their research helpful. Together, we can ensure that emergency responses are supported by the best-available S&T to inform the protection of lives, property, and the environment. Although the differing groups may focus on different objectives, in the end, we all are working to improve disaster response, recovery, and future preparedness.

3.2 A Systems Approach is Needed

Although trusting relationships are the foundation for any productive interaction between the EM and S&T communities, these partnerships would not work without functional mechanisms for collaboration. Mechanisms like S&T advisor positions, data clearinghouses, research coordination networks, and standardized communication protocols make smooth interactions between these sometimes-disparate communities possible in times of great stress. Removing or limiting administrative barriers for funding these collaborations further paves the way to the seamless integration of science and disaster response.

3.3 Innovation May Not Always Happen

Some events may be so chaotic or occur on such an accelerated pace that research may not be possible. Although standard S&T data products (for example, meteorological data) may be used during such an event, it may be too risky or disruptive to allow innovative research to be conducted during or immediately after a response. In these cases, the S&T community could seek to understand what conditions made their interventions inappropriate or impossible and determine if any of these conditions could be overcome or changed before the next event. This analysis may lead to future opportunities that enable or improve future S&T interventions.

3.4 Emergency Management and S&T Cultures are Different

The objectives of emergency managers and researchers in a response may be dramatically different. Though one group may have a singular focus on the protection of life and property over the short term, the other may have a focus on data collection for analysis that may take months or years. If these two groups are able to effectively communicate and interact with each other in a respectful and safe manner, this difference in cultures can be managed. S&T liaisons, advisors, or advisory groups can bridge these cultural gaps by translating scientific findings or needs into language that is actionable and understood by the EM community and relaying the needs of this community back to scientists and engineers. Flexibility and resiliency are key to successfully bridging the ideological and practical gaps between these two communities.

A Final Challenge

EM practitioners and S&T researchers in the hazard and disaster field have demonstrated a long-standing commitment to protect lives, property, and the environment. But at present (2021), both groups are experiencing critical challenges to their professional practice. As disasters increase in frequency and magnitude, so too does the pressure on EM personnel to respond while S&T researchers may move quickly from one disaster to the next with no clear mechanism for ensuring the application of the results.

Meeting these 21st century challenges requires EM and S&T workforces to be well-trained, well-resourced, nimble, and large enough to address increasing demands (National Research Council, 2006; Peek and others, 2020). Thus, we end this report reminding the readers of the grand workforce challenge associated with all the key points in this report. We not only need excellent rapport and collaboration between the EM and S&T communities, but we also need more well-trained, well-equipped personnel in both communities. Although building this critical workforce is a challenge for many reasons, it is also an opportunity to think differently about how we train these groups. Ensuring that mutual and effective lines of collaboration, understanding, and respect are “baked in” to the training process may create new and more effective means of responding to disasters in the future.

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Annexes

Annex 1. Table of Abbreviations

This list of acronyms is not comprehensive to all those used in the report. It seeks to highlight acronyms used frequently across the report.

Abbreviation	Definition
BHSP	Board on Health Sciences Policy
CDC	Centers for Disease Control
DHS	Department of Homeland Security
DOI	Department of the Interior
DR2	Disaster Research Response (Program)
EERI	Earthquake Engineering Research Institute
EM	emergency management
EPA	U.S. Environmental Protection Agency
ESF	Emergency Support Function
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIOP	Federal Interagency Operational Plan
ICS	Incident Command System
IMET	Incident Meteorologist
IOM	Institute of Medicine
IPQG	Incident Position Qualification Guide
IRB	Institutional Review Board
HUD	Department of Housing and Urban Development
MA	Mission Assignment
NASA	National Aeronautics and Space Administration
NASEM	National Academies of Science, Engineering, and Medicine
NBSB	National Biodefense Science Board
NDRF	National Disaster Recovery Framework
NEHRP	National Earthquake Hazard Reduction Program
NIH	National Institutes of Health
NIMS	National Incident Management System
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPS	National Preparedness System
NRF	National Response Framework
NSF	National Science Foundation
NSTC	National Science and Technology Council
NWIRP	National Windstorm Impact Reduction Program
NWCG	National Wildfire Coordination Group
NWS	National Weather Service

Abbreviation	Definition
OFCM	Office of the Federal Coordinator for Meteorology
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
PRA	Paperwork Reduction Act
PSMA	Pre-Scripted Mission Assignment
RAPID	Grants for Rapid Response Research (NSF program)
RAPIDD	Rapid Acquisition of Pre- and Post-Incident Disaster Data
RSF	Recovery Support Function
S&T	science and technology
SDR	Subcommittee on Disaster Reduction (changed to Science for Disaster Reduction in 2019)
SOP	Standard Operating Procedure
USACE	U.S. Army Corps of Engineers
USAID	U.S. Agency for International Development
USGS	U.S. Geological Survey

Annex 2. Other Work in this Field

Multiple reports and articles have explored the use of science for response and have identified numerous best practices as well as policy recommendations to advance this capability:

Colwell and Machlis (2019)

Published by the American Academies of Arts and Sciences, this report focuses on conducting scientific research during disasters. It also focuses on data collection, communication, and considering how to effectively integrate the scientific science and technology community into disaster response.

Mease and others (2017)

This article in "Ecology and Society" documents the outcomes of the Science Partnerships Enabling Rapid Response Project, which was led by Stanford University's ChangeLabs in 2014–15. Authors applied human-centered design thinking to analyze collaboration among academic, Government, and industry scientists, decision makers, and responders using the Deepwater Horizon oil spill as a case study. The article characterizes obstacles to scientific collaboration; identifies effective tools, protocols, and practices that enable effective exchange between those response groups and scientists; and proposes a "Science Action Network" as a potential solution to improve coordination and integration of science and technology resources into disaster response.

National Biodefense Science Board (2011)

This report is a call to action for the Federal Government to better incorporate scientific investigations into emergency preparedness and response. Focusing on public health disasters, the report offers recommendations as to how to better mobilize scientific resources.

Coastal Response Research Center (2019)

In 2019, the Coastal Response Research Center and the National Oceanic and Atmospheric Administration co-sponsored a workshop titled "Leveraging Science and Academic Engagement During Incidents," which focused on the integration of academic resources and expertise into a conventional oil spill response. The goal of this workshop was to provide focused discussion regarding lessons learned from academic engagement during oil spill response with participants from industry, Government, and academia. The final report documents the findings of this workshop.

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Annex 3. Example of a Science Management Team

Below is an example of a hypothetical science response structure that would be used to address a new large-scale eruption of Kilauea volcano. This management team could fall under Emergency Support Function 5, information and planning (Federal Emergency Management Agency, 2016). Typically, the Federal Emergency Management Agency would mission-assign an Emergency Support Function that is led by a particular agency, and that agency would reach out to its partners to provide responders. In this example, the U.S. Geological Survey would be the lead agency and would staff the Event Response Coordinator position. Note there are several science response positions because the response to an urban volcanic eruption would require multiple scientific tasks. The different pieces of this science management team would function in concert with the appropriate sections of the Incident Command System (ICS). For example, the Event Response Coordinator would function as a liaison to the traditional ICS Command and General Staff, the Science Operations Chief would fall under the Science Branch in traditional ICS Operations, and the Unmanned Aircraft System Coordinator would fall under traditional ICS Air Operations.

Reference Cited

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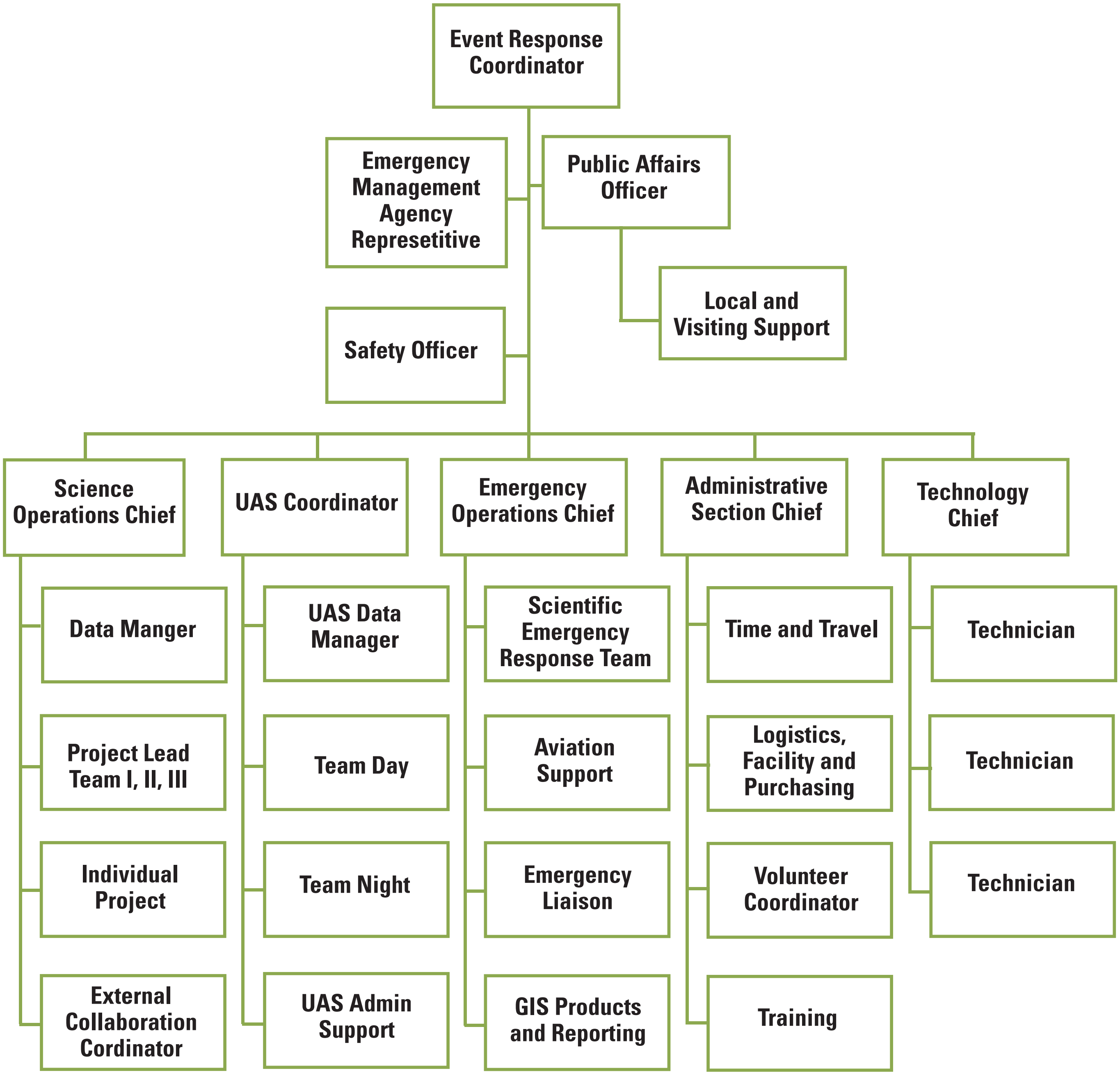

Figure 3.1. Example Scientific Management Team for volcano science response. [UAS, Unmanned Aircraft System; GIS, Geographic Information System]

Annex 4. Summary of Challenges

Below is a summary of the challenges discussed in section 2 of this report. The challenges are listed in order of appearance in the text and are not ranked.

Summary of Challenges
Design research protocols for disasters before disaster strikes.
Ensure that communities are a part of research design before disasters.
Provide scientists with rapid funding and equipment for research.
Provide mechanisms to provide expedited Institutional Review Board approval for human-subjects related research during disasters.
Design and implement a strategy for Office of Management and Budget approvals of information collections (for example, surveys and interviews) through the Paperwork Reduction Act (44 U.S.C. 3501 et seq.) that includes mechanisms such as umbrella Office of Management and Budget/Paper Reduction Act clearances or expedited/emergency clearances that allow researchers to rapidly implement standardized data-collection instruments.
Ensure that scientists and engineers seeking to enter disaster areas to perform research do so respectfully.
Ensure that scientists and engineers performing research in disaster-affected areas do so safely.
Build trusting relationships between researchers and responders before disasters.
Ensure researchers are aware of emergency response frameworks, terms, and protocols to navigate responses safely and effectively.
Ensure that scientists and engineers seeking to conduct research in disaster-affected areas are self-sufficient to avoid placing further burdens on supplies, communities, and facilities.
Ensure that scientific information is provided to those who need it at the right time and in useful formats during a disaster.
Ensure that research and scientific findings are discussed in a credible and respectful way.
Develop protocols for addressing conflicting research findings and communicating scientific uncertainty during a disaster.
Standardize data collection and analyses during hazard response.
Standardize data collection and analyses across multiple disaster events.
Coordinate data collection during response across the research community to minimize redundant efforts.
Archive, catalog, and curate data collected during a disaster to inform future research.

Annex 5. Pre-Scripted Mission Assignments

Below is a list of Pre-Scripted Mission Assignments (PSMAs) across the interagency that are relevant to the use of science and technology during disaster response. This list is subject to change and is current as of the publication of this report (2021).

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
EPA PSMA ESF 10 - 149	(HQ) Activation: EPA	ESF 10: Oil and Hazardous Materials Response	U.S. Environmental Protection Agency (EPA) to National Response Coordination Center (NRCC) or other teams and facilities as requested	As directed by and in coordination with Federal Emergency Management Agency (FEMA), the EPA will provide appropriate personnel to the NRCC, or other teams and facilities as requested, to support disaster operations (FEMA, 2016b).
EPA PSMA ESF 10 - 153	(DFA) Oil and HAZMAT Assessment, Response and Removal Incident Management Team	ESF 10: Oil and Hazardous Materials Response	EPA oil and hazardous materials field operations for disaster operations	In support of State/Territory/Tribal request, as directed by and in coordination with FEMA, the EPA will conduct oil and hazardous materials field operations, including cleanup and disposal of hazardous materials and oil and response to orphaned containers in support of FEMA disaster operations. These necessary emergency protective measures will mitigate actual and potential threats to public health and safety. The EPA response may also include the following: household hazardous waste collection and disposal, and monitoring of immediate public health and safety threats resulting from debris removal operations. The EPA will coordinate activities involving contaminated debris with the U.S. Army Corps of Engineers (USACE) as appropriate. Actions may include support by any special teams requested by the Federal On-Scene Coordinator (FOSC) and approved by FEMA, as well as special technical assets of all ESF 10 support agencies (FEMA, 2016b).

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
EPA PSMA ESF 10 - 152	(DFA) Oil and HAZMAT Technical Analysis : Mobile Platform	ESF 10: Oil and Hazardous Materials Response	EPA technical analysis of potential impacted areas for oil and hazardous materials from aerial platforms	In support of State/Territory/Tribal request, as directed by and in coordination with FEMA, the EPA will conduct from mobile platform(s) the technical analysis of potential impacted areas for oil and hazardous materials in support of disaster operations. This support is necessary to mitigate actual and potential threats to public health and safety. The EPA response may include air, soil, or water contaminant detection, as well as surveillance or monitoring of immediate public health and safety threats. The EPA is responsible for providing personnel and (or) equipment necessary to accomplish the mission (FEMA, 2016b).
EPA PSMA ESF 10 - 151	(DFA) Oil and HAZMAT Technical Analysis : Aircraft - fixed wing (ASPECT)	ESF 10: Oil and Hazardous Materials Response	EPA technical analysis of potential impacted areas for oil and hazardous materials from aerial platforms	In support of State/Territory/Tribal request, as directed by and in coordination with FEMA, the EPA will conduct from aerial platform(s) the technical analysis of potential impacted areas for oil and hazardous materials in support of FEMA disaster operations. This support is necessary to mitigate actual and potential threats to public health and safety. The EPA response may include air, soil, or water contaminant detection, as well as surveillance or monitoring of immediate public health and safety threats. The EPA is responsible for providing personnel and (or) equipment necessary to accomplish the mission (FEMA, 2016b).
EPA PSMA ESF 10 - 149	(FOS) Activation: EPA	ESF 10: Oil and Hazardous Materials Response	Activate EPA to Regional Response Coordination Center (RRCC), Initial Operating Force (IOF), Joint Field Office (JFO), or other teams and facilities as requested	As directed by and in coordination with FEMA, the EPA will provide appropriate personnel to RRCC, IOF, JFO, or other teams and facilities as requested to support disaster operations. Funding for EPA command center(s), if authorized by FEMA, will be provided under a separate Mission Assignment (MA) (FEMA, 2016b).

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
DOI PSMA ESF 11 - 123	(FOS) Archaeology, Historic, Cultural, Tribal SMEs	ESF 11: Agriculture and Natural Resources	Request U.S. Department of the Interior (DOI) deploy specialty subject-matter experts (SMEs) to provide expertise in support of FEMA response operations.	As directed by and in coordination with FEMA, DOI will provide SMEs in support of FEMA response operations. The support provided may include, but is not limited to, the following (FEMA, 2008b): Archeologists Biologists, Fisheries Specialists, and Threatened and Endangered Species Specialists Global Positioning System (GPS) Specialists and Geographic Information System (GIS) specialists Historic Preservation Specialists, Architectural Historians, Historic Architects, Historic Building Technology Specialists and Cultural Landscape Architects Hydrologists, Fish Passage Engineers, Biologists, and Fluvial Geomorphologists Ethnographers or Anthropologists Tribal Specialists
DOI PSMA ESF 11 - 120	(DFA) Archaeology, Collections, Historic Environments SMEs	ESF 11: Agriculture and Natural Resources	DOI specialty SMEs to provide expertise	In support of State/Territory/Tribal request, as directed by and in coordination with FEMA, DOI will provide appropriate personnel to the RRCC, IOF, JFO, or other teams or facilities to support disaster operations. The support provided may include, but is not limited to, the following (FEMA, 2008b): Archeologists Curators, Conservators and Museum Specialists Historic Preservation Specialists, Architectural Historians, Historic Architects, Historic Building Technology Specialists and Cultural Landscape Architects

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
DOE PSMA ESF 12 - 114	(FOS) Federal Radiological Monitoring and Assessment / FRMAC	ESF 12: Energy	U.S. Department of Energy (DOE) environmental radiological monitoring/Federal Radiological Monitoring and Assessment Center (FRMAC)	As directed by and in coordination with FEMA, DOE, through the National Nuclear Security Administration (NNSA), will conduct environmental radiological monitoring, which may include establishment and operation of the FRMAC in support of FEMA response operations. DOE will deploy personnel to perform any or all of the tasks including, but not limited to, the following (FEMA, 2016c): Reach-back assistance to technical expertise in atmospheric and environmental modeling, and characterizing and identifying radioisotopes Data analysis and spatial representation of radiological conditions Radiological monitoring and collection of air, soil, water, and so on to analyze for radioactive contamination (20 two-person survey teams and both fixed and rotary-wing aircraft as appropriate) Provide capabilities for collection of all sample media related to human ingestion pathways for radioactive materials Radiological surveys of public buildings and structures Process and ship radioactive samples to radioanalytical laboratories for analysis Manage and support a large number of field teams when integrated with first responders already on scene and responders from other Federal agencies

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
DOE PSMA ESF 12 - 115	(FOS) National Atmospheric Release Advisory Center Scientists/ Technicians	ESF 12: Energy	DOE: National Atmospheric Release Advisory Center (NARAC) in support of disaster operations.	As directed by and in coordination with FEMA, DOE, through the NNSA, will activate the NARAC to determine the nature and extent of a radiological release and use field data to update NARAC model predictions in support of FEMA response operations. Support provided by nondeployed specialists, technicians, and other support personnel may include, but is not limited to, the following (FEMA, 2016c): Data analysis and production of atmospheric dispersion hazard predictions Technical support for users of the Consequence Management (CM)/ NARAC Web system Management of the NARAC response staff Communication with other organizations Interpretation of results
DOD PSMA ESF 5 - 84	(DFA) Imagery Support	ESF 5: Information and Planning	U.S. Department of Defense (DOD) imagery support via air and/or land for damage assessments and (or) situational awareness	In support of State/Territory/Tribal request, as directed by and in coordination with FEMA, DOD will provide imagery support via air/land for damage assessments and (or) situational awareness in support of disaster operations (FEMA, 2016a).

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
USGS PSMA ESF 5 - 395	(FOS) Documenting Flood Water Heights	ESF 5: Information and Planning	Field measurements of flood-water heights in impacted communities	As directed by and in coordination with FEMA, the U.S. Geological Survey (USGS) will provide advance support, real-time field measurements, and daily reporting of water heights in direct support and for situational awareness of FEMA disaster operations for a high-water or flood event. USGS services may include, but are not limited to, the following in direct support of response and recovery operations (FEMA, 2016a): Field measurements of flood water heights in impacted communities; Deploy supplemental water-level measuring instruments. Measure streamflow and discharge of flooded channels, directly or indirectly. Flagging of high-water marks (HWMs) and collect evidence of flooding for impacted areas and communities. Locate and record the horizontal position and vertical elevation of the HWMs. Documentation of HWMs with field notes, digital photographs, and depth measurements to the ground at the HWM location at the time of inspection. Data measurements provided in GIS-ready format via the USGS National Water Information System or Short-Term Network system for display and download.

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
USCG PSMA ESF 5 - 332	(DFA) Damage Assessment and/or Situational Awareness: Imagery	ESF 5: Information and Planning	U.S. Coast Guard (USCG) provide personnel and (or) assets to conduct post-event images and (or) imagery collection (aerial/ waterborne/ terrestrial) to support State/Territory/Tribal disaster operations.	In support of a State/Territory/ Tribal request, as directed by and in coordination with FEMA, USCG will acquire still and (or) motion images/imagery from aerial and (or) waterborne and (or) terrestrial assets, and distribute data to designated exploitation elements for further analysis and inclusion in situational awareness and damage assessment products to State/Territory/Tribal support disaster operations (FEMA, 2016a).
NOAA PSMA ESF 5 - 203	(DFA) NOAA Marine Debris Assessment SMEs	ESF 5: Information and Planning	Request the National Oceanic and Atmospheric Administration (NOAA) deploy science support personnel to provide coordination and scientific support for debris removal in response to acute marine debris events for State/Territory/ Tribe in support of FEMA response operations.	As directed by and in coordination with FEMA, NOAA will activate Marine Debris Program staff to calibrate pre-event models and maps, assess needs, and coordinate debris removal with appropriate Federal, State, and local agencies, including FEMA and USACE, in support of FEMA response operations. NOAA will collect information and work with the NOAA home team to deliver marine debris scientific support. This support includes Marine Debris Program working in concert with stakeholders and partners to identify needs and develop maps, models, and decision-support tools for debris response and removal including: shoreline, aerial, and underwater debris mapping; model and track debris fate and movement; risk estimates of the potential effect of debris based on its type, trajectory, or the species and habitats affected; and provide information on the potential risks to communities of debris containing hazardous materials (FEMA, 2016a).

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
NOAA PSMA ESF 5 - 201	(DFA) NOAA Hydrographic Surveying SMEs and Equipment	ESF 5: Information and Planning	Request NOAA deploy hydrographic personnel and equipment to provide emergency hydrographic surveys, obstruction location, and vessel traffic rerouting for State/Territory/Tribe in support of FEMA response operations.	As directed by and in coordination with FEMA, NOAA responders and (or) hydrographic surveying contractors will mobilize and implement actions in support of the National Response Framework (NRF) ESF 1 annex to conduct emergency hydrographic surveys, obstruction location, and vessel traffic rerouting in ports and waterways, and to support search and recovery in support of FEMA response operations. NOAA will deploy to the Marine Transportation System Recovery Unit in the USCG Incident Command System Planning Unit and coordinate with FEMA ESF 1 desk at the JFO, or other facilities as requested. The task order will direct NOAA and (or) contractor assets and personnel to survey affected areas as assigned by NOAA following consultation with and direction from the USCG and FEMA. Hydrographic data from the disaster area will be collected, processed, and distributed in graphical format to the primary coordinator, support agencies, and FEMA as directed. Information provided can be used to support the rapid restoration of the Marine Transportation System and the movement of emergency supplies (FEMA, 2016a).

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
NOAA PSMA ESF 5 - 200	(DFA) NOAA Aerial Imagery/ LIDAR: NOAA Aircraft, Remote Sensing Aerial Survey Crew, and Equipment	ESF 5: Information and Planning	NOAA aircraft, survey crew, and remote sensing equipment to provide information regarding the nature and extent of an incident and cascading effects	In support of State/Territory/Tribal request, as directed by and in coordination with FEMA, NOAA will provide support that may include, but is not limited to, rapidly collecting, processing, and distributing high resolution, geo-rectified aerial imagery and (or) Light Detection and Ranging (lidar) data in support of disaster operations NOAA personnel will participate in Interagency Remote Sensing Coordination Cell (IRSCC) planning meetings, provide technical and operational planning expertise to facilitate aerial survey planning, and coordinate survey operations with other agencies (via the IRSCC, if activated) (FEMA, 2016a).

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
NOAA PSMA ESF 5 - 202	(DFA) Support for Oil and Chemical Spills: NOAA Science Support SMEs	ESF 5: Information and Planning	Request NOAA deploy science support personnel to provide support for modeling pollutants (air and water), resource and chemical/ hazard assessment, analytical chemistry support and data management for State/Territory/Tribe in support of FEMA response operations.	As directed by and in coordination with FEMA, NOAA's Office of Response & Restoration will provide scientific support and comprehensive solutions to environmental hazards caused by oil, chemicals, and marine debris in support of FEMA response operations. Potential support may include, but is not limited to the following (FEMA, 2016a): Serving as a scientific support coordinator, coordinating within NOAA, with other Federal, State, and local agencies as needed. Providing oceanographic modeling and forecasts of pollutant transport. Synthesizing of real time ocean data, including water levels, tidal currents, and water temperatures for use in decision making. Providing information and data management tools for science-based decision making and common operational picture support. Providing air dispersion estimates of toxic gases, in conjunction with Interagency Modeling and Atmospheric Assessment Center where appropriate. Providing assessments of environmentally sensitive habitats and species in the coastal environment and recommendations on protection or appropriate response activities.

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
NOAA PSMA ESF 5 - 199	(DFA) NOAA Geodetic Surveys: NOAA Topographic Survey Crew and Equipment	ESF 5: Information and Planning	Request NOAA deploy geodetic field survey crews and equipment to provide situational awareness for emergency response and long-term infrastructure systems and public works repair for State/Territory/Tribe in support of FEMA response operations.	As directed by and in coordination with FEMA, NOAA will support the NRF ESF 3 annex through the deployment of geodetic survey crews to conduct terrestrial leveling and GPS/Global Navigation Satellite System (GPS/GNSS) surveys for assessment of change in vertical and horizontal positions in support of FEMA response operations. This may require repair or establishment of temporary or permanent Continuously Monitored Reference Stations (CORS) as necessary that provide precise GPS/GNSS positioning. Survey crews will participate in planning meetings, provide technical and operational planning expertise to facilitate topographic survey planning, coordinate survey operations with other agencies, and coordinate with the FEMA ESF 3 desk at the JFO (FEMA, 2016a).
NOAA PSMA ESF 5 - 198	(FOS) Support to Hurricane Liaison Team: NOAA NWS SMEs	ESF 5: Information and Planning	NOAA/National Weather Service (NWS) meteorological and hydrological on-site expertise, coordination, and analysis in support of the FEMA Hurricane Liaison Team (HLT)	As directed by and in coordination with FEMA, NOAA/ NWS will deploy personnel to provide meteorological and hydrological on-site expertise, coordination, and analysis in support of the FEMA HLT and FEMA disaster operations (FEMA, 2016a).
NOAA PSMA ESF 5 - 194	(FOS) Activation: NOAA, NS, or NOS	ESF 5: Information and Planning	Activate NOAA to RRCC, IOF, JFO, or other teams or facilities to support disaster operations.	As directed by and in coordination with FEMA, NOAA will provide appropriate personnel to the NRCC to support disaster operations. This may include, but is not limited to, the following (FEMA, 2016a): NWS meteorologist(s) and (or) hydrologist(s) National Ocean Service (NOS) personnel with coastal resource and management expertise Support to ESF 5 to provide meteorological onsite expertise, coordination, and analysis

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
NGA PSMA ESF 5 - 188	(FOS) Activation: NGA	ESF 5: Information and Planning	Activate the National Geospatial-Intelligence Agency (NGA) to RRCC, IOF, JFO, or other teams and facilities	As directed by and in coordination with FEMA, the NGA will provide appropriate personnel to the RRCC, IOF, JFO, or other teams and facilities to support disaster operations (FEMA, 2016a).
NGA PSMA ESF 5 - 191	(FOS) Geospatial Intelligence (GEOINT) for Rapid Needs Assessment (RNA) Team: Geospatial Analyst Type III Team	ESF 5: Information and Planning	NGA Geospatial Intelligence (GEOINT) assistance for FEMA Regional Rapid Needs Assessment (RNA) Team	As directed by and in coordination with FEMA, the NGA will provide a Geospatial Analyst Type III team to assist the FEMA Regional RNA Team in support of disaster operations (FEMA, 2016a).
NGA PSMA ESF 5 - 193	(HQ) Geospatial Intelligence (GEOINT) for NRCC	ESF 5: Information and Planning	NGA GEOINT to the NRCC in support of disaster operations.	As directed by and in coordination with FEMA, the NGA will provide geospatial analysts with contractor support to supplement GIS production at the NRCC in support of FEMA response operations (FEMA, 2016a).
NGA PSMA ESF 5 - 192	(FOS) Geospatial Intelligence (GEOINT)	ESF 5: Information and Planning	NGA GEOINT to the RRCC, IOF, or JFO	As directed by and in coordination with FEMA, the NGA will provide GEOINT to the RRCC, IOF, JFO, or other teams or facilities in support of disaster operations (FEMA, 2016a).

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
NGA PSMA ESF 5 - 190	(FOS) Geospatial Intelligence (GEOINT) for US&R: Geospatial Analyst Type I Team	ESF 5: Information and Planning	NGA GEOINT for FEMA Urban Search and Rescue (US&R)	As directed by and in coordination with FEMA, the NGA will deploy the Geospatial Analyst Type I Team to assist the US&R Incident Support Team and deployed task forces in support of disaster operations. Support includes, but is not limited to, the following (FEMA, 2016a): Mobile Integrated Geospatial Intelligence System (MIGS) or DMIGS, its domestic version NGA analysts to provide analytical expertise NGA operational support staff including contractors to support operations, satellite communications, and sheltering and feeding of NGA staff (a total of 12 personnel to provide mobile GEOINT)

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
HHS PSMA ESF 8 - 238	(DFA) HHS Consultants/ Scientific Experts	ESF 8: Public Health and Medical Services	Health and Human Services (HHS) consultation and scientific expertise to assist state and local public health authorities in support response operations	In support of State/Territory/Tribal, as directed by and in coordination with FEMA, HHS will provide appropriate personnel to provide guidance to State and local staff in developing necessary health actions/precautions for the public health response. Consultation may include any or all of the following (FEMA, 2008a): At-Risk Coordination: Provide consultation in medical human services program coordination for at-risk population needs to ensure that appropriate Federal benefits are delivered to the impacted population. Deploy at-risk team(s) to coordinate with State, local, and other Federal agencies to identify whether and how Government programs may be adjusted to meet the needs of the disaster victims and expedite new enrollments for Federal benefits needed that result from the disaster. Food Safety and Inspections: Provide guidance on what steps, if any, should be employed to restore drugs, biologics, medical devices, and food to a condition fit for use. Provide guidance to state and local disaster response personnel in food safety, preparation, handling, and storage. Environmental Health: Provide guidance and scientific expertise to local staff who are evaluating environmental conditions in the affected area and provide recommendations to improve the situation.

PSMA Identifier	PSMA Title (Source of Funding)	Emergency Support Function (ESF)	Assistance Requested (Description)	Statement of Work
HHS PSMA ESF 8 - 245	(DFA) Environmental Health -Hazard Identification and Control Measures: HHS water/ wastewater SMEs	ESF 8: Public Health and Medical Services	HHS environmental health hazard identification and control measures in support of disaster operations	In support of State/Territory/Tribal request, as directed by and in coordination with FEMA, HHS will assist State and local staff in evaluating environmental conditions and impacts on human health, and where possible, work to start public health interventions and control measures to lessen effects in the affected area. Work may include, but is not limited to, the following (FEMA, 2008a): Potable water and groundwater issues Wastewater and human waste disposal Sanitation for emergency shelter operations Toxin abatement Vector control

References Cited

Federal Emergency Management Agency, 2008a, Emergency Support Function #8—Public health and medical services annex: Federal Emergency Management Agency, 15 p., accessed December 19, 2020, at https://www.fema.gov/pdf/emergency/nrf/nrf-esf-08.pdf.

Federal Emergency Management Agency, 2008b, Emergency Support Function #11—Agriculture and natural resources annex: Federal Emergency Management Agency, 16 p., accessed December 19, 2020, https://www.fema.gov/pdf/emergency/nrf/nrf-esf-11.pdf.

Federal Emergency Management Agency, 2016a, Emergency Support Function #5—Information and planning annex: Federal Emergency Management Agency, 4 p., accessed December 19, 2020, at https://www.fema.gov/sites/default/files/2020-07/fema_ESF_5_Information-Planning.pdf.

Federal Emergency Management Agency, 2016b, Emergency Support Function #10—Oil and hazardous materials response annex: Federal Emergency Management Agency, 16 p., accessed December 19, 2020, at https://www.fema.gov/sites/default/files/2020-07/fema_ESF_10_Oil-Hazardous-Materials.pdf.

Federal Emergency Management Agency, 2016c, Emergency Support Function #12—Energy: Federal Emergency Management Agency, 12 p., accessed December 19, 2020, at https://www.fema.gov/sites/default/files/2020-07/fema_ESF_12_Energy-Annex.pdf.