IDENTIFYING SCIENCE AND TECHNOLOGY OPPORTUNITIES FOR NATIONAL PREPAREDNESS

PRODUCT OF THE
Subcommittee on Disaster Reduction
OF THE Committee on Environment, Natural Resources, and Sustainability
OF THE NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

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The Subcommittee on Disaster Reduction (SDR) is a Federal interagency subcommittee of the U.S. National Science and Technology Council's Committee on Environment, Natural Resources, and Sustainability. First chartered in 1988, the SDR provides a unique Federal forum for information sharing, development of collaborative opportunities, formulation of science- and technology-based guidance for policy makers, and dialogue with the U.S. policy community to advance informed strategies for managing disaster risks. Under its mandate, the SDR advises the White House Office of Science and Technology Policy (OSTP) and others about risk reduction resources and the related work of SDR Member Agencies. More information is available at www.sdr.gov/.

About the National Preparedness Science and Technology Task Force

The National Preparedness Science and Technology (NPST) Task Force was chartered under the Subcommittee on Disaster Reduction in November 2014 to integrate science and technology (S&T) into all facets of national preparedness across the Federal Government. The NPST Task Force was charged with assessing the status of Federal S&T opportunities across the mission areas established in Presidential Policy Directive 8, and designing a structured process to identify and prioritize efforts for S&T program planning between the Federal interagency S&T community and the national preparedness community.

About this Document

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SUBCOMMITTEE ON DISASTER REDUCTION
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Executive Summary

Presidential Policy Directive 8 (PPD-8: National Preparedness) and the National Preparedness Goal establish the overarching principles for national preparedness policy, which aims to achieve "a secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk." The National Preparedness Goal describes a set of core capabilities necessary for the achievement of all-hazard preparedness. Science and technology investments support the development and provision of these core capabilities by advancing fundamental understanding of how and why hazards occur, observation and monitoring capabilities to understand changes in natural phenomena or to detect movement of dangerous materials or substances, technology to protect first responders and affected populations, and information to provide situational awareness during a disaster.

The National Science and Technology Council's Subcommittee on Disaster Reduction formed the National Preparedness Science and Technology Task Force to coordinate the Federal science and technology community with the "preparedness community" to support national preparedness. Collaboration among the Federal science and technology communities and the "preparedness community" represents a new approach to joint planning that ensures science and technology outcomes are relevant to the needs of emergency managers and decision makers responsible for protecting the Nation against all hazards. Joint planning between these two Federal communities adds value toward meeting the respective mission of each, which would not be achieved through independent planning efforts.

In 2005, the Subcommittee on Disaster Reduction published a set of Grand Challenges for Disaster Reduction[1] based primarily on input from Federal scientists who work on disaster-related topics. The National Preparedness Science and Technology Task Force builds upon the Grand Challenges effort by engaging the National Preparedness community as well. This natural extension of the Grand Challenge process, ensuring collaboration of both users and producers of science and technology (S&T), fits the spirit of whole-community engagement for preparedness as described in the National Preparedness Goal.

The Task Force assembled six teams of subject matter experts from across the Federal Government to assess S&T opportunities to better prepare for biological hazards, chemical hazards, radiological and nuclear hazards, geological hazards, meteorological hazards, and space hazards (including hazards from both space weather and Near-Earth Objects (NEOs)). The Task Force analyzed the products of the six teams and identified a set of cross-cutting S&T development areas, all of which relate to national preparedness capabilities, that were common to all six hazard types studied. The six cross-cutting S&T development areas identified by the Task Force are:

1. **Improve Public Communication of Warnings and Advisories**: S&T capabilities in this category aid the development of new approaches, tools, and platforms to communicate accurate and timely information to the public. This category includes research into social science, risk communication, communications technology, and education and outreach.
2. **Enhance Fundamental Understanding of Hazards**: This category includes research exploring the underlying principles and processes that generate hazards. Federal S&T efforts advance research that support and advance an understanding of how physical, chemical, biological, natural, or social processes occur.

[1] National Science and Technology Council (NSTC), Subcommittee on Disaster Reduction, *Grand Challenges for Disaster Reduction*, June 2005, http://www.sdr.gov/docs/SDRGrandChallengesforDisasterReduction.pdf.

3. **Improve Event Characterization and Risk Assessment**: These applied research activities help emergency managers and decision makers understand risks associated with potential hazards (e.g., by mapping where hazards are most likely to occur and predicting their magnitude) and provide tools to characterize an event as new information and data become available.

4. **Enhance Observations, Modeling, and Data Management**: The Federal government maintains a wide range of hazard-focused Earth observations. These observations and associated technology increase the ability of scientists and managers to detect changes in the environment (such as the dispersion of a dangerous substance), develop models to advance predictive capabilities, and deploy capabilities to manage data and information resources to make them more useful to emergency managers and decision makers.

5. **Develop Technology for Safer, Effective, and Timely Response and Recovery**: Advances in response and recovery technology provide emergency managers and responders with the tools needed to safely and quickly make decisions and operate in a potentially dangerous situation. S&T research activities include new technology development, such as improving protective equipment, as well as protocols and guidelines to ensure that emergency managers and responders take actions necessary to protect themselves and others.

6. **Integrate Science into Preparedness Decisions**: The focus of this category is ensuring that decision makers, including emergency managers, have the most accurate, relevant, and timely information necessary to make decisions and that it is communicated in highly useful ways. Improvements in products or educational tools that ensure decision makers have access to the best-available scientific information across all five mission areas is an important contribution from the science and technology community.

In addition to the six S&T development areas, the analysis suggested that further S&T opportunities for hazard preparedness are best understood as falling into three multi-hazard categories as opposed to the "all-hazards" approach used in preparedness planning. The first category includes biological, chemical, and radiological and nuclear hazards, which often derive from human-influenced or -induced events. The second category includes meteorological and geological hazards, which both originate from Earth-based natural phenomena. The last group consists of space-based hazards, space weather and NEOs.

The National Preparedness System aims to ensure that preparedness capabilities are developed at every level of government, the private sector, and non-profit sector, so that each is prepared to carry out its roles and responsibilities. Toward this end, future collaborative activities to identify and develop important S&T capabilities should expand to include dialogue with external stakeholders, including the private sector, local, state, and tribal governments, and academia. The Task Force anticipates that continued collaboration will lead to long-term improvements in the Nation's ability to protect lives and property, and increase resilience to all types of hazards.

Introduction

Purpose Statement

National preparedness critically depends on Federal science and technology (S&T) resources. Notable examples include science activities before, during, and after Hurricane Sandy in 2012; the Deepwater Horizon oil spill in the Gulf of Mexico in 2010; and the Tōhoku earthquake, tsunami, and Fukushima Daiichi nuclear incident in 2011. For all three events, Federal agencies provided pre- and post-event aerial and satellite imagery for purposes of protection (including warnings), response, and recovery; technical modeling and forecasting for purposes of protection, mitigation, and response; and rapid dissemination of damage assessment data to guide response and facilitate recovery. To date, though, S&T resources, plans, and goals relevant to national preparedness are not integrated systematically into national preparedness planning.

Presidential Policy Directive 8 (PPD-8),[2] *National Preparedness*, requires a comprehensive, coordinated, all-of-Nation approach to preparedness. Coordination between the Federal S&T community and the preparedness community is necessary, not only to ensure that future research activities are responsive to operational capability needs but also to build a dynamic capacity to utilize hazards-related S&T to support disaster mitigation, response, and recovery.

Background

The *National Preparedness Goal* (Goal)[3] establishes the focus and core capabilities to support national preparedness; and the *National Preparedness System* (System)[4] identifies the tools, processes, and systems to build, sustain, and deliver those capabilities. The System addresses government, private, nonprofit, and public activities in order to achieve an integrated, layered, all-hazards, all-of-Nation preparedness approach that optimizes use of available resources.

The Goal, in brief, is to achieve "a secure and resilient nation with capabilities required across the whole community[5] to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk." The Goal defines a set of nationally unified activities for all-hazards preparedness, called core capabilities, in five mission areas – prevention, protection, mitigation, response, and recovery (Table 1). Developing the capacity to carry out the 32 core capabilities is necessary at every level of government, the private sector, and non-profit sector so that each is prepared to carry out its roles and responsibilities in fulfilling the Goal.

To further describe the overall concepts, principles, and policies related to each of the five mission areas, the Federal Government worked with a broad array of external stakeholders to develop the *National*

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2 Executive Office of the President (EOP), *Presidential Policy Directive / PPD-8: National Preparedness*, March 30, 2011, http://www.dhs.gov/presidential-policy-directive-8-national-preparedness.

3 Department of Homeland Security (DHS), *National Preparedness Goal*, Second Edition, September 2015, http://www.fema.gov/media-library-data/1443799615171-2aae90be55041740f97e8532fc680d40/National_Preparedness_Goal_2nd_Edition.pdf.

4 DHS, *National Preparedness System*, November 2011, http://www.fema.gov/media-library-data/20130726-1855-25045-8110/national_preparedness_system_final.pdf.

5 FEMA's definition of whole community is available here: https://www.fema.gov/whole-community

Planning Frameworks (Frameworks).[6] The Frameworks describe key roles and responsibilities across governmental and non-governmental sectors, including individuals and families, businesses, community groups, and nonprofit organizations. The Frameworks, in turn, are supported by five *Federal Interagency Operation Plans* (FIOPs),[7] which explain how the Federal Government aligns resources and delivers core capabilities within each mission area. Together the Goal, the Frameworks, and the FIOPs provide the whole preparedness community with a common set of doctrine with common terminology, clear roles and responsibilities, and an understanding of the interdependencies needed to prepare the Nation for addressing risks posed by all potential threats and hazards.

Table 1: The National Preparedness Mission Areas and Core Capabilities

Mission Area	Description	Core Capabilities
Prevention	The capabilities necessary to avoid, prevent, or stop a threatened or actual act of terrorism. Within the context of national preparedness, the term "prevention" refers to preventing imminent threats	• Planning • Public Information and Warning • Operational Coordination • Intelligence and Information Sharing • Screening, Search and Detection • Interdiction and Disruption • Forensics and Attribution
Protection	The capabilities necessary to secure the homeland against acts of terrorism and manmade or natural disasters	• Planning • Public Information and Warning • Operational Coordination • Access Control and Identity Verification • Cybersecurity • Intelligence and Information Sharing • Interdiction and Disruption • Physical Protective Measures • Risk Management for Protection Programs and Activities • Screening, Search, and Detection • Supply Chain Integrity and Security
Mitigation	The capabilities necessary to reduce loss of life and property by lessening the impact of disasters.	• Planning • Public Information and Warning • Operational Coordination • Community Resilience • Long-term Vulnerability Reduction • Risk and Disaster Resilience Assessment • Threats and Hazards Identification
Response	The capabilities necessary to save lives, protect property and the environment, and meet basic	• Planning • Public Information and Warning • Operational Coordination • Critical Transportation

6 FEMA, *National Protection Framework*, http://www.fema.gov/national-protection-framework-0. FEMA and its partners released the most recent updates to the Framework on June 16, 2016.

7 FEMA, *Federal Interagency Operational Plans*, November 9, 2016, http://www.fema.gov/federal-interagency-operational-plans.

Mission Area	Description	Core Capabilities
	human needs after an incident has occurred	• Environmental Response/Health and Safety • Fatality Management Services • Fire Management and Suppression • Infrastructure Systems • Logistics and Supply Chain Management • Mass Care Services • Mass Search and Rescue Operations • On-scene Security, Protection, and Law Enforcement • Operational Communications • Public Health, Healthcare, and Emergency Medical Services • Situational Assessment
Recovery	The capabilities necessary to assist communities affected by an incident to recover effectively	• Planning • Public Information and Warning • Operational Coordination • Economic Recovery • Health and Social Services • Housing • Infrastructure Systems • Natural and Cultural Resources

Source: Department of Homeland Security. *National Preparedness Goal*, Second Edition, September 2015, http://www.fema.gov/media-library-data/1443799615171-2aae90be55041740f97e8532fc680d40/National_Preparedness_Goal_2nd_Edition.pdf.

S&T relevant to national preparedness extends from fundamental process research, applied science, and translational applications. Together these advance fundamental understanding of hazards and their underlying physical, chemical, and biological processes, information products to support decisions, and technology to support core capabilities in each of the five mission areas. S&T investments have aided emergency managers, first responders, and officials responsible for protecting communities from hazards and mitigating risks posed by them. Enhanced coordination between Federal officials responsible for developing preparedness policy, doctrine, and capabilities and S&T officials responsible for national research programs will ensure future S&T investments address emerging national preparedness needs.

Chartering the National Preparedness Science and Technology Task Force

The National Science and Technology Council's Subcommittee on Disaster Reduction, Office of Science and Technology Policy staff recognized the need for a common forum where Federal agencies responsible for developing and advancing science and technology and agencies responsible for deploying capabilities to ensure the Nation is prepared for all-hazards could coordinate their respective activities to meet common objectives. The National Preparedness Science and Technology Task Force was chartered to provide this forum where the Federal science and technology community and National Preparedness community can come together to openly assess progress toward meeting preparedness goals and identify opportunities for science and technology to ensure the Nation is prepared for future incidents. The Task Force's charter calls for the Task Force members to:

1. Assess the current status of Federal S&T investments across the five PPD-8 mission areas by leveraging the *National Preparedness Report* and other sources, including evaluating current progress on the SDR's Grand Challenges for Disaster Reduction implementation plans.

2. Design a structured process for use by departments and agencies to identify and prioritize efforts between the Federal interagency S&T community and the national preparedness community for S&T program planning under PPD-8.

This report presents the results of the Task Force's efforts to identify ways S&T enhances preparedness capabilities for all hazards and promising paths forward for improved preparedness, in fulfillment of the two charter functions presented above. The process is intended as a first step toward increased coordination and collaboration between scientists and decision makers and emergency managers. The report is intended to inform the policy development process and is not intended as a budget document.

Insights from the Task Force Assessment of Science and Technology Supporting National Preparedness

Development of a Science and Technology Priority Assessment Process

The Task Force designed and implemented a process to assess current S&T opportunities to support preparedness across all PPD-8 mission areas. Recognizing the long-term nature of planning for S&T priorities, the Task Force considered S&T activities from all stages of R&D – from the development of new technologies to support decision makers to fundamental research into natural systems, which could yield S&T for preparedness years after research has begun. Science and technology investments often occur within hazard-specific fields of research or practice, which creates difficulties in designing an all-hazard S&T planning process within preparedness policy and doctrine.

To address these challenges, the Task Force charged six interagency teams with identifying how S&T supports preparedness capabilities within the five mission areas (as described by the National Preparedness Goal). Each of the six interagency teams was assigned a set of hazards and threats: (1) biological, (2) chemical, (3) radiological and nuclear, (4) meteorological, (5) geological, and (6) space-related (including space weather and Near-Earth Objects). They were also each asked to address all five mission areas.

Table 2 describes the specific hazards considered by each group. The lists of hazards were derived from the *Strategic National Risk Assessment.*[8]

Table 2: Hazard Areas and Specific Considerations

Hazard Area	**Specific Hazards Considered (based upon *Strategic National Risk Assessment* and interagency working group determination)**
Biological	Animal Disease Outbreak; Biological Food Contamination; Biological Terrorism Attack (non-food); Biological Food Contamination Terrorism Attack; Human Pandemic Outbreak
Chemical	Chemical Substance Spill or Release; Chemical Terrorism Attack (non-food); Chemical Food Contamination Terrorism Attack
Radiological and Nuclear	Radiological Substance Release; Nuclear Terrorism Attack; Radiological Terrorism Attack
Geological	Earthquake; Landslide; Tsunami; Volcanic Eruption
Meteorological	Drought; Flood; Heat Wave; Hurricane; Tornado; Wildfire; Winter Storm
Space	Near-Earth Object; Space Weather

This process built upon the Subcommittee on Disaster Reduction's previous Grand Challenge and Implementation Plan development process. For the Grand Challenges, Federal science and technology experts identified preparedness-related S&T needs and opportunities across agencies. This effort resulted in hazard-specific implementation plans. Since PPD-8 emphasizes all-community and all-hazard preparedness, the current process engaged members of the Federal preparedness community as well as from the Federal S&T community.

[8] DHS, "The Strategic National Risk Assessment in Support of PPD 8: A Comprehensive Risk-Based Approach toward a Secure and Resilient Nation," https://www.dhs.gov/xlibrary/assets/rma-strategic-national-risk-assessment-ppd8.pdf.

Each team was co-led by a Federal Emergency Management Agency (FEMA) or Department of Homeland Security (DHS) official familiar with operational requirements for a "user" perspective, and a Federal agency representative responsible for managing S&T programs, to provide a provider perspective. Each team was asked to: (1) identify existing Federal S&T programs that support the goals of the mission areas, and (2) identify and describe potential opportunities to employ science and technology toward supporting mission area requirements. The Appendix describes the team-specific input on how Federal S&T activities support preparedness for the team's given set of hazards.

Implementation of the Assessment Process

The following two sections describe the Task Force's findings related to cross-cutting S&T capability categories that are relevant to all-hazards and a set of high-priority S&T opportunities identified through the application the cross-cutting categories. The assessment involved a two-step process: (1) developing cross-cutting S&T development areas relevant to all hazards, and (2) applying them to identify high priority S&T opportunities. The assessment process fulfilled the Task Force's charter responsibility to design a structured process to prioritize S&T opportunities relevant to both Federal communities.

Identification of Cross-Cutting Science and Technology Development Areas

To begin, each hazard team assessed the current state of S&T activities supporting preparedness needs for their hazard. Then a content analysis was performed on each team's submission, to identify common terms and topics relevant to all six teams and across all PPD-8 mission areas. This content analysis yielded six categories that describe the most promising areas of opportunity for S&T to support all-hazard preparedness. These categories are referred to as cross-cutting science and technology capability categories.

Since this all-hazard list was generated by a collaboration between Federal S&T users and producers, it is anticipated that it will be more valuable for agency planning and decision making purposes than assessments developed by S&T officials alone. In addition, it is anticipated that the process of collaboration has enhanced understanding and support between S&T users and producers, and that this will, in itself, enhance coordination, collaboration, and preparedness going forward. Finally, it is anticipated that these conversations and this report can serve as a starting point for future discussions on how S&T can continue to contribute to preparedness capabilities with a broader set of interested stakeholders, including state, local, and tribal governments responsible for deploying S&T capabilities at local levels as well as non-governmental scientists who are interested in performing research to improve the Nation's state of preparedness.

The six cross-cutting science and technology development areas are:

❶ **Improve Public Communication of Warnings and Advisories:** S&T opportunities to advance public communication of warnings and advisories span a large area of scientific investment, including social science, risk communication, communications technology development, or education and outreach efforts to enhance two-way communication between communities and decision makers responsible for issuing warnings and advisories. These opportunities generally aim to support public communication rather than decision making by elected officials or other emergency management officials. S&T that hardens communications infrastructure or increases system redundancy are included in this category.

❷ **Enhance Fundamental Understanding of Hazards:** Fundamental research advances understanding of the physical, chemical, or biological processes behind hazard phenomena, and how these processes evolve within physical, living, and built environments. Technology developers and applied researchers build on fundamental findings in order to produce tools for response and decision making, like detection and protection technologies, forecasts and projections, and response options.

❸ **Improve Event Characterization and Risk Assessment**: S&T efforts that enable event characterization, forecast tracks, risk assessment, damage assessment, and related tools are essential to experts and emergency management officials in assessing hazards and associated risks. Applied research and technology development efforts that support event characterization or risk assessment prior to an event include hazard magnitude and frequency mapping, vulnerability assessment approaches or methodologies, and design standards. Research and technology development support post-event characterization include sampling protocols, modeling, and impact and damage assessment approaches that provide situational awareness and predict consequences.

❹ **Enhance Observations, Modeling, and Data Management:** Earth observations; surveillance methods and technologies; models to understand and estimate effects; and management of data on hazards, infrastructure, and populations are all important supports for the preparedness mission areas. These observations, models, and data are the basis for sensing changes in the environment and translating those measurements into risk- and decision-relevant preparedness information. Long-term data management efforts are important so that scientists can understand trends and relationships associated with hazards that may take place over long timescales (e.g., drought, pandemics, and climate change).

❺ **Develop Technology for Safer, Effective, and Timely Response and Recovery:** Response and recovery technology capabilities provide information, tools, and measures for emergency response officials to maintain situational awareness, to make informed decisions, and to ensure hazards are appropriately addressed. For example, these capabilities might include protocols for the collection and disposal of hazardous materials, standards for communications technology, or methods and technologies for detection and cleanup of environmental (chemical, biological, and radiological) contamination.

❻ **Integrate Science into Preparedness Decisions:** Accurate, timely, and relevant science, delivered in ways that are readily understood and acted upon, are needed by emergency management officials, community decision makers, and the public in order to ensure appropriate actions are taken to protect lives and property. Opportunities in this category focus on supporting emergency management officials' or community officials' decisions before, during, or after an event. Opportunities in this category include outreach and education to train decision makers to understand warnings and advisories, and S&T leading to decision support tools that translate scientific input into locally decision-relevant information.

More Specific Findings

In the second step of the assessment process, the Task Force identified more specific S&T opportunities that were common to all hazards. This content analysis indicated that, in fact, S&T opportunities for hazard preparedness are better understood as falling into a few somewhat similar hazard groups, rather than into a single all-hazards category.

Three multi-hazard categories emerged in the analysis. The first set consists of biological, chemical, and radiological and nuclear hazards, which often derive from human-influenced or -induced events. The second includes meteorological and geological hazards, which both originate from Earth-based natural phenomenon. The last group consists of space-based hazards: space weather and Near-Earth Objects (NEOs). Although space hazards are natural hazards like those in the second set, the space hazard category is distinct in terms of scope and scale of impact, the non-terrestrial nature of the entities involved, and the level of international collaboration required to address these hazards.

The specific opportunities below relate to both the cross-cutting categories identified above and the capabilities they enable fit within mission areas. In the descriptions below, each potential opportunity is tagged with numbered icons associated with the six cross-cutting development areas and with the most relevant mission area(s).

1. **The biological, chemical, radiological, and nuclear hazards teams emphasized several of the same types of S&T opportunities to support mitigation, response, and recovery phase capabilities.**

   1.1. *Informed mitigation requires the ability to characterize an event rapidly by identifying the agent used, area exposed, and population at risk.* Effective positioning and deployment of technical capabilities, such as surveillance and detection assets, requires planning to identify potential scenarios, evaluate vulnerabilities, and estimate associated risks to populations. These capabilities also inform early response phase priorities and actions. ❸❹❺(**Response**)

   1.1.1. *Advanced characterization capabilities require development of high-resolution detection technologies to determine the presence of a hazard after its release and to provide warning before clinical cases appear.* Mitigation and early phase response to biological, chemical, radiological, and nuclear hazards rely upon technical means of detecting when an agent has been released. Increasing the sensitivity of detection technology to identify agents at longer distances and lower concentrations enables mitigation actions to be taken prior to exposure and prompts earlier indication of hazards to promote earlier deployment of response assets (e.g., through Emergency Support Function #8—Public Health and Medical Services). ❸❺ (**Response**)

   1.2. *Once the release of a biological, chemical, radiological, or nuclear agent is detected, S&T capabilities are required to characterize the threat posed by the release and to carry out effective and timely response and recovery actions.* Advances in technical capabilities, such as rapid and accurate screening protocols, medical countermeasure production, and assessment methodologies to determine environmental exposures (e.g., food, water, facility, and area contamination) and their impacts will improve capabilities to effectively minimize exposure, stop spread of contamination, and enable effective remediation, and restoration. ❸❹❺ (**Protection, Response, Recovery**)

   1.2.1. *Opportunities for research and technology in rapid threat analysis of unknown agents will help with determining the fate and transport of a released agent, including, for example, how long it will survive outside the human body, the impact it will have on the environment, and the potential threats it poses to first responders.* Rapid agent threat characterization is essential for planning and prioritizing response and recovery efforts, including identifying exposed populations, establishing exclusion zones, and determining decontamination and medical care requirements. ❷❸❺ (**Response, Recovery**)

   1.2.2. *An improved understanding of the fate and transport of agents and their interaction with critical infrastructure and the environment would improve vulnerability assessments and real-time modeling capabilities during emergency response to inform decisions.* Comprehensive modeling of agent fate and transport would inform assessment tools used and guidance documents developed for effective management of critical infrastructure during response operations. In addition, such modeling tools would help identify priority monitoring locations for collecting real-time data to ascertain continuing functionality of critical infrastructure, such as the electric power grid, for response operations. ❷❺❻ (**Mitigation, Response, Recovery**)

1.3. *Emergency response plans must be actionable.* The technical tools, trained personnel, information-sharing platforms, protective equipment, and medical resources outlined in response plans must be readily available for responders to successfully manage a disaster. ❺❻ (**Response**)

1.3.1. *Technology development requires addressing the demand surge for environmental surveillance and detection assets following an event (e.g., deployable satellites, ships, aircraft, remotely-operated devices, sampling equipment, and technicians).* Real-time monitoring is essential to fully characterize the nature, level, and geographic scope of the event and to ascertain the functionality of critical infrastructure for response operations; rapid deployment of field diagnostics is necessary to identify exposed individuals and contaminated infrastructure at risk. ❸❺ (**Mitigation, Response**)

1.3.2. *Increasing and improving training for technical staff and the public health workforce is necessary to provide sufficient response capabilities.* Protocols and decision aids, such as technologies to support responder training for novel hazards, must be developed and practiced to facilitate thorough and rapid response; guidance needs to be put in place to communicate just-in-time release of sensitive information. ❺❻ (**Response**)

1.3.3. *Development of sufficient laboratory infrastructure to accommodate a surge for real-time crisis research, including medical countermeasure development and rapid, agent-specific risk assessments, is important to support response efforts.* Rapid development and deployment of diagnostic assays and medical countermeasures are imperative to minimize loss of life; research into broad-spectrum medical countermeasures that can be stockpiled without refrigeration would support this need. ❺ (**Mitigation, Response**)

2. **The geological and meteorological hazards emphasized similar S&T opportunities. While their hazards pose distinct risks, preparedness for these hazards share common S&T capabilities.**

2.1. *Improvements in knowledge and fundamental understanding of the mechanisms underlying the initiation and propagation of geological and meteorological hazards would greatly enhance preparedness.* Continued investments in research into how geological hazards initiate, such as triggering of ground shaking or landslides, and in understanding the underlying physical, chemical, and biogeochemical processes of meteorological hazards will provide the foundation for all other capabilities associated with geological and meteorological hazard preparedness. There is also a need for research into the triggering and interaction of multiple hazard processes. ❷❸ (**Protection, Mitigation**)

2.1.1. *Risk assessments would be more effective with improved forecasting capabilities and reduced probabilistic uncertainty in hazard modeling.* Scientific opportunities in improved forecasting and long-term probabilistic hazard assessments will reduce risk assessment uncertainty by providing more accurate hazard exposure data and information. ❸ (**Protection, Mitigation, Response**)

2.2. *Expansion and sustainment of Earth observation systems are a key element in advancing meteorological and geological hazard-prediction capability.* Earth observations are used in models and forecasting tools to estimate exposure to and consequences of geological and meteorological hazards. Essential Earth observations maintain and advance capabilities to forecast the intensity, structure, and track of these types of hazards. ❸❹ (**Protection, Mitigation, Response, Recovery**)

2.2.1. *Increases in density and availability of Earth observation in high-risk, or underserved locations are needed to expand coverage of monitoring and predictive capabilities.* S&T such as expanded coverage of real-time, continuous GPS data and ocean measurements would enhance mitigation and response capabilities to underserved locations. ❹ (**Mitigation, Response**)

2.2.2. *Increases in Earth observation density combined with other data sources yield networks of sensors that can serve as the foundation for an advance warning system.* Location-specific applications of Earth observations and infrastructure or building system sensors when paired with communication systems and protocols collectively can provide the foundation for an advance warning system for geological and meteorological hazards. ❶❸❹ (**Protection, Mitigation**)

2.2.3. *Expansions in observation systems could provide higher-resolution data on post-disaster response and recovery of systems and on secondary effects of events.* Earth observation data after an event have significant scientific value and help characterize the risk of ongoing events (e.g., earthquake aftershocks and volcanic activity). These data from an expanded or deployable observation system could provide critical information for deployment of emergency resources and personnel or assessment of damage. ❸❹ (**Response, Recovery**)

2.2.4. *Sustained deployment of high priority Earth observations is essential for calibration and validation of predictive hazard models.* Models that forecast hazard activity or provide information on hazard exposure level rely upon real-world data for calibration and validation. Sustainment of key Earth-observing assets that provide data on geological and meteorological hazards is essential for maintaining or improving accuracy and reliability of model-based forecasting. ❹ (**Protection, Mitigation, Response**)

2.3. *Improvement in translation of hazards forecasts to decision support tools is needed to increase the utility of information generated.* Output from scientific products may not be immediately meaningful to users such as emergency managers or community decision makers. Translation of these scientific results into useful information and decision support tools requires plans or processes that pair the development of these tools with user information needs. ❻ (**Response, Recovery**)

2.3.1. *Opportunities for engagement among emergency managers and community decision makers through training in scientific decision support, for example, would enhance the transition of research outcomes to operational capabilities.* Effective education and training enables decision makers to make decisions on preparedness actions and investments that are informed by relevant information from scientific models and interpretation of assessed risk and uncertainty. ❻ (**Protection, Mitigation, Response, Recovery**)

3. Space hazards present unique hazards and S&T challenges. The unique origin of these hazards necessitates the development of hazard-specific capabilities to detect, characterize, and develop approaches to eliminate the risk posed.

3.1. *S&T opportunities exist to clearly link observations and event predictions to consequences.* Enhanced forecasting tools, techniques, and processes to further fundamental understanding of space weather and NEO events would support risk management and inform mitigation and resiliency strategies. ❷❸ (**Protection, Mitigation, Response**)

3.1.1. *Advancing understanding of occurrences, behavior, and consequences of space weather events and NEOs of various sizes would improve the effectiveness of risk assessments and reduce uncertainty in models.* More accurate, geographically specific capabilities in space weather forecasting would increase warning lead times and help protect critical infrastructure. In addition, improved models demonstrating the behavior of asteroids once they enter Earth's atmosphere would help characterize impact consequences, including analyzing threat to life, that could inform planning and response decisions. ❷❸❹ (**Protection, Mitigation, Response**)

3.1.2. *Modeling efforts would inform vulnerability assessments of critical infrastructure to space weather events and NEO impacts.* Improved monitoring, cataloging, and modeling would help identify vulnerabilities and develop plans for strategic infrastructure resiliency opportunities and inform risk management strategies to protect space-based, sea-based, and terrestrial assets, such as the electric power grid and other critical infrastructure. ❷❸❹ (**Protection, Mitigation**)

3.2. *Improvements in observation capabilities can help meet space hazard preparedness needs.* Forecasting and early warning capabilities rely on real-time, continuous monitoring and detection provided by an array of space-and ground-based observational sensors. ❷❹ (**Protection, Mitigation, Response**)

3.2.1. *Long-term strategic planning would help ensure the continuation of key observational networks. Strategic plans should reflect assessment of observation needs and options for* upgrading or expanding existing capabilities. ❹ (**Protection, Mitigation, Response**)

3.3. *Research and technology advances in NEO disruption and deflection capabilities should be prioritized in the development of emergency action plans in order to comprehensively assess risk and compare alternative responses.* S&T to determine efficacy and risks of NEO deflection/disruption efforts and improved modeling to better estimate casualty and property loss are critical to developing decision support tools. ❷❺❻ (**Mitigation, Response**)

3.3.1. *An agreed-upon set of forecasting parameters that trigger emergency action is needed as part of a comprehensive emergency response plan.* Risk assessments can inform protocols to aid in decisions about when to deploy reconnaissance missions, when to engage the international community, and when to deploy NEO deflection/disruption actions. International participation in such efforts requires the development of a threat notification process to communicate information about probability, impact location, and predicted effects to the international community. ❸❻ (**Mitigation, Response**)

Conclusion

This report presents the results of joint efforts by Federal officials in both the S&T and the national preparedness communities to identify how S&T enhances preparedness capabilities for all hazards. The findings illustrate how joint planning among the Federal science and technology communities and the preparedness policy community can add value to the individual communities' national preparedness efforts. Ultimately, the successful development and deployment of scientific products to support preparedness will require a whole of community approach. The Task Force hopes this report can lead to dialogue with a broader set of stakeholders, including local, state, and tribal governments responsible for employing these capabilities to protect their communities, and foster engagement with non-governmental scientists and the academic community who have an interest in contributing S&T advances to prepare the Nation.

Abbreviations

BDRD	Biodefense Research and Development Subcommittee
CDC	Center for Disease Control
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOT	Department of Transportation
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FOSC	Federal On-Scene Coordinator
FRMAC	Federal Radiological Monitoring and Assessment Center
GPS	Global Positioning System
HHS	Department of Health and Human Services
IMAAC	Interagency Modeling and Atmospheric Assessment Center
LIDAR	Light Detection and Ranging
MCMH	4-Methylcyclohexanemethanol
NASA	National Aeronautics and Space Administration
NEHRP	National Earthquake Hazards Reduction Program
NEO	Near-Earth Object
NGA	National Geospatial-Intelligence Agency
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Heath
NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NPST	National Preparedness Science and Technology
NRC	Nuclear Regulatory Commission
NSF	National Science Foundation
NSTC	National Science and Technology Council
NWS	National Weather Service
OSTP	Office of Science and Technology Policy

PIERWG	Planetary Impact Emergency Response Working Group
PPD-8	Presidential Policy Directive 8
S&T	Science and Technology
SDR	Subcommittee on Disaster Reduction
SNRA	Strategic National Risk Assessment
STEM	Science, Technology, Engineering, and Math
SWAP	Space Weather Action Plan
USDA	Department of Agriculture
USGS	United States Geological Survey

Appendix: Summary of Science & Technology in Support of National Preparedness

This appendix provides an overview of how current Federal science and technology programs investments aid and support preparedness capabilities. Each section was developed by a Federal interagency team with representation from the science and technology community and the National Preparedness community. Each section describes the scope of current hazards posed to the Nation, examples of events of incidents where science and technology has supported preparedness, and a description of the role of science and technology in preparing for a given set of hazards.

Biological Hazards

Present-day trends such as the increase in global travel and heavier antibiotic use in healthcare and agriculture have increased the risk of outbreak posed by some biological hazards, as seen recently in the spread of the Zika and Ebola viruses. These instances and others have also demonstrated the key role that S&T occupies for national preparedness. For example, improved biosurveillance can help the Federal government detect outbreaks quickly and manage them effectively. Research and development of vaccines, pharmaceuticals, and diagnostics can advance patient treatment and mitigate the spread of an outbreak. Better designed personal protective equipment can ensure that health workers and their patients reduce their exposure to biohazards.

The biohazard team exclusively considered threats from natural disease outbreaks in its analysis. A risk assessment of biological weapons attacks and proposed S&T actions for preparedness are addressed in the Homeland Biodefense Science and Technology Capability Gap Review, developed by the NSTC Biodefense Research and Development (BDRD) Subcommittee.[9]

Roles of Federal Science and Technology in Ensuring National Preparedness

A number of Federal agencies, departments, and partners are guided by the National Planning Frameworks to support the five mission areas. These agencies include the U.S. Departments of Health and Human Services, Agriculture, Justice, Interior, Defense, Commerce, and Homeland Security, as well as the Environmental Protection Agency.[10] Science and technology provides knowledge and tools to these entities so that they may act effectively in these mission areas. For instance, HHS is responsible for surveillance of pathogen outbreaks and transmission, so as to aid early detection and inform response decision making. DHS coordinates messages to the public alongside HHS and local officials, and therefore benefits by communication technologies and messaging strategies. The public health system initiates protective and responsive measures for the affected population, including vaccination, prophylaxis, and treatment. HHS and DHS work jointly to identify and isolate contaminated persons, cargo, mail, or conveyances entering the United States, and HHS partners with USDA to quarantine affected food, animals, or other agricultural products.[11]

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[9] NSTC, Biodefense Research and Development Subcommittee, *Homeland Biodefense Science and Technology Capability Gap Review*.

[10] NSTC, *Biological Response and Recovery Science and Technology Roadmap*, October 2013, https://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/brrst_roadmap_2013.pdf.

[11] FEMA, *National Response Framework*, "Biological Incident Annex," https://www.fema.gov/pdf/emergency/nrf/nrf_BiologicalIncidentAnnex.pdf.

Preparedness Science and Technology Capability Needs

Considering these services and others provided by the Federal government with respect to a biological incident, the following objectives represent key capabilities to be achieved in the mission areas.

- With regard to the protection area: effective risk communication prior to and during an outbreak, risk assessments for biohazard scenarios, improved capacity to rapidly assess fate and transport (including biopersistence and fomite/vector transmission), and establishment of baselines from which to detect biohazards.
- With regard to the mitigation area: improved personal protective equipment, reporting and data collection for tracking of outbreaks, and rapid point of care diagnostics.
- With regard to the response and recovery areas: biohazard-specific patient treatment guidelines, preventative alternatives to antibiotics, and waste management and environmental decontamination measures.

Chemical Hazards

Science and technology opportunities yield improved capabilities for all levels of chemical incident preparedness. They enable understanding of the effects of chemicals on the environment and the toxicity of chemical substances, both of which support characterization of potential health impacts on humans and wildlife for prevention, protection, mitigation, response, and recovery purposes. They enable sensor technology to detect chemical agents and rapidly characterize potential exposures and risks to populations or the environment, as well as enabling safe and effective medical responses. S&T investments also underpin early warning capabilities to prevent or reduce exposures to human populations, and materials science and engineering to improve personal protective equipment for first responders.

A recent chemical spill in West Virginia illustrates the roles of science and technology in supporting chemical accident and threat preparedness. On January 9, 2014, an estimated ten thousand gallons of crude 4-Methylcyclohexanemethanol (MCHM) spilled into the Elk River near Charleston, West Virginia, less than two miles upstream from a West Virginia American Water Company's water intake location.[12] [13] In response to the spill, scientists from the U.S. Centers for Disease Control and Prevention (CDC) were deployed to advise the West Virginia Department of Health and Human Resources. The CDC responded to the State of West Virginia's request to develop a short-term screening-level for drinking water, finding that a screening level of 1 ppm or less is not likely to be associated with adverse health effects.[14] This work was reviewed by a Federal interagency group that included the CDC, EPA, NIEHS, and NIH. Using the CDC's screening level findings and toxicity data provided by the manufacturer to inform their guideline, West Virginia public health officials established an upper limit of 1 part per million of MCHM as safe for human consumption. The EPA also responded to the event by providing science and technology support for

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[12] State of West Virginia, After Action Review, Emergency Reponses to January 9, 2014 Freedom Industries Chemical Leak. http://www.governor.wv.gov/Documents/After%20Action%20Review.PDF

[13] FEMA, "West Virginia Chemical Spill" Disaster Declaration, https://www.fema.gov/disaster/3366.

[14] CDC, "Summary Report of Short-term Screening level Calculation and Analysis of Available Animal Studies for MCHM." January 20, 2014. https://emergency.cdc.gov/chemical/MCHM/westvirginia2014/pdf/MCHM-Summary-Report.pdf

chemical fate and transport as well as analytical chemistry, and by developing a vapor inhalation screening level for responders involved with site cleanup. As the event continued, the public demanded increased levels of sampling, exposure, and toxicological data to provide evidence in support of safety assurances. As the situation evolved, emergency officials shared the scientific assessments of conditions and safety levels in order to build credibility and trust in the safety guidelines being shared with the public. The rapid availability of human toxicity data for MCHM, together with the engagement of scientific expertise and methods, was essential; it enabled fast, trusted, evidence-based decisions during this accidental chemical spill.[15]

Roles of Federal Science and Technology in Ensuring National Preparedness

Federal agency science and technology support for chemical preparedness is primarily focused on providing support for detection, containment, decontamination, attribution, and decision support for mitigation, response, and recovery mission areas.

Federal agencies such as the EPA and the CDC are called upon to support the assessment, monitoring, and clean-up of hazardous materials. Roles such as these are key to characterization of the extent of contamination after a release, decontamination activities, and identification and treatment of potentially exposed individuals. EPA's Federal On-Scene Coordinators (FOSCs), when responding to environmental emergencies, can receive technical support from the breadth of expertise of leading-edge environmental scientists in EPA's Office of Research and Development. The CDC's Agency for Toxic Substances and Disease Registry employs teams of epidemiologists, toxicologists, and exposure scientists to conduct public health assessments and health consultations for communities that have experienced hazardous substance releases. The National Toxicology Program (NTP), which is managed by NIEHS, provides toxicologists and laboratory capacity to characterize chemical hazards, while scientists at NIEHS can assess their potential health impacts on exposed populations. NIEHS, in partnership with NIH, also sponsors the Disaster Research Response Program that brings together communities, emergency management, worker health and safety, public health, and academic scientists of health disciplines to build national capacity for health-related research following disasters. DHS Science and Technology Directorate has invested in research into chemical detection, response, and recovery capabilities. For maritime spills, including oil spills, the U.S. Coast Guard maintains FOSCs, which are supported by a scientific support team and coordinators that advise on relevant scientific issues as they arise. The science support coordinators serve on the FOSC staff, per the National Contingency Plan. NOAA maintains a science support team that can be called upon by the NOAA science support coordinator to advise the FOSC staff with in-house science capabilities and outreach to the broader scientific community.

Preparedness Science and Technology Capability Needs

Across mitigation, response, and recovery mission areas, chemical hazard preparedness capabilities fall into general categories of detection, protection, containment, decontamination, treatment, and attribution. Detection refers to the ability to detect the presence, identification, and quantity of a hazardous chemical substance released into the environment. Protection includes the equipment worn by responders to guard against their exposure to chemical hazards during their operations. Containment refers to protocols, technologies, and materials that are used to secure a site where a spill or release has taken place and prevent the further spread of the contamination. Decontamination consists of procedures taken by emergency responders to remove and safely treat or dispose of contaminated media (e.g., soil, groundwater, building materials). Treatment is the medical assistance provided to individuals

[15] State of West Virginia, After Action Review, Emergency Reponses to January 9, 2014 Freedom Industries Chemical Leak. http://www.governor.wv.gov/Documents/After%20Action%20Review.PDF. Ibid, **Error! Bookmark not defined.**.

that may have been exposed to the hazardous chemical substance. Attribution capabilities provide Federal officials with information necessary to identify the origin and root cause of the substance release and take action to prevent recurrence.

Within the mitigation mission area, science and technology investments support core capabilities related to vulnerability reduction, threat and hazard characterization, and cross-cutting capabilities for planning. In support of mitigation capabilities, Federal agencies invest to develop knowledge and understanding about the fundamental properties of chemical agents, how chemical agents behave in and affect the environment, and what effects they cause in humans and animals. Improved understanding of the behavior and toxicity of released hazardous chemicals, as well as chemicals used to treat released chemicals, can inform a wide variety of decisions made during disaster mitigation, response, and recovery, including those related to advisories made to the public.

In the response mission area, a key objective of the Federal government when responding to a chemical-related disaster, as described in the National Response Framework, is to provide guidance and resources to first responders and the public on the threats posed by any released hazardous materials or chemical weapons[16]. To meet this objective, Federal scientists conduct health hazard assessments, which are foundational for core capabilities relating to environmental response, health and safety, mass care services, public health, healthcare, emergency medical services, and situational awareness. Medical countermeasure research investments are another important area of scientific support; they aim to improve the health outcomes of individuals exposed to chemical agents by developing diagnostics that help identify actual exposed individuals and treatments appropriate to those exposed. There are S&T opportunities to more quickly characterize exposure and contamination after a chemical release. Federal research to improve and harmonize sampling and analysis methods can improve the information used in response decisions. Sampling and analysis improvements present opportunities to contribute to improved capabilities for attribution, which is particularly important in identifying individuals who may be responsible for intentional releases.

In the recovery mission area, scientific investments aim to develop and improve decontamination methods and technologies. Findings from this area of research could reduce the impact of clean-up efforts on commerce and public activities. Science and technology supporting recovery capabilities can lead to advances in decontamination procedures, methods, and techniques that reduce the impacts to and amount of time needed for communities to rebuild after an event.

Radiological and Nuclear Hazards

Preparing for a nuclear or radiological incident or event[17] requires a whole-of-government approach. As described in the Strategic National Risk Assessment, nuclear and radiological hazards and threats can be separated into the following groups: (1) accidental radiological substance releases, such as a release from a damaged nuclear reactor core; and two types of adversarial threats, (2) nuclear terrorism threats, in which a hostile non-state actor acquires and detonates an improvised nuclear weapon within a major U.S. population center; and (3) radiological terrorism threats, in which a hostile non-state actor acquires and

[16] FEMA, *National Response Framework*, May 2013, http://www.fema.gov/media-library-data/20130726-1914-25045-1246/final_national_response_framework_20130501.pdf.

[17] An incident is commonly referred to as an unplanned for occurrence while an event is an occurrence with some level of advanced knowledge of the occurrence. For purposes of this report, event and incident will be used synonymously (as incident) unless the focus of the content exclusively applies only to events.

disperses radiological materials or creates a radiation exposure device.

Many capabilities related to nuclear and radiological preparedness originate from investments in science and technology research and development. Critical scientific and technology capabilities include the ability to detect radiological materials in transit, in the atmosphere, and in the environment, and the ability to model their transport and dispersion; forensic capabilities that enable attribution; capabilities to enhance the Nation's nonproliferation policies; and event response capabilities to aid individuals and communities affected by an attack or accident. The deployment of these capabilities relies upon a sustained scientific and technical workforce that can augment existing capabilities and rapidly deploy in response and recovery related roles.

On-going R&D efforts being performed by various Federal organizations remain essential for the community for enhancing capability related to preparedness, response, recovery, and mitigation to radiological and nuclear events. Over the past half-century, the focus of core R&D investments has shifted from fundamental understanding of nuclear physics (i.e., what are the risks?) to the understanding of incident characterization and hazard assessment (i.e., how to better mitigate and address the risk). Moving forward, priorities in nuclear and radiological R&D is to ensure the necessary investments in forensics and attribution; intelligence and information sharing; interdiction and disruption; and screening, search, and detection.

In the context of response and recovery, the focus is to support and enhance technology and science integration into decision making. R&D efforts that can expedite the collection, process, and distribution of accurate and timely information will improve decision making, response integration (e.g., Federal, state, and tribal), crisis communications (e.g., translate scientific information in a manner to be understood and applied by non-scientific audiences), improvement in capability, and the improvement in the application of appropriate resources.

Events such as the Tohoku earthquake and associated Fukushima Daiichi Nuclear power plant disaster in 2011 highlight the roles associated with the deployment of Federal science and technology assets to support nuclear and radiological preparedness. Observations and modeling were employed to predict the transport, dispersion, and deposition of radioactive materials. Immediately following the disaster, the U.S. Department of Energy's National Nuclear Security Administration (NNSA) sent 33 people and 8.6 tons of equipment to Japan to assist efforts to monitor radiation. This included consequence management response teams. The NNSA aerial system took thousands of radiation readings over the next two weeks. [18] Following the incident, as part of the response and recovery process, the Nuclear Regulatory Commission (NRC) formed a task force to review and identify lessons learned to reduce the risk of a similar accident occurring at a U.S. nuclear power facility. The NRC task force issued recommendations that were adopted by the Commission in 2012 to require backup generation for cooling water pumps, enhanced water level monitoring capabilities, and improved emergency venting systems to relieve pressure in a serious accident.[19]

Large scale radiological or nuclear incidents like the Fukushima Daiichi disaster occur very infrequently and are extremely complex. As a result, specialized nuclear and radiological plans and capabilities are heavily reliant on exercises. The difficulty to design exercises that simulate the full complexity of the real-

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[18] Nuclear Street, "DOE to Continue Radiation Monitoring and Other Assistance in Japan," http://nuclearstreet.com/nuclear_power_industry_news/b/nuclear_power_news/archive/2011/03/29/doe-to--continue-radiation-monitoring-and-other-assistance-in-japan032903#.V__qNNUrJEY.

[19] U.S. Nuclear Regulatory Commission, "Recommendations for Enhancing Reactor Safety in the 21st Century. The Near-Term Task Force Review of Insights from the Fukushima Daiichi Accident," 2011, http://pbadupws.nrc.gov/docs/ML1118/ML111861807.pdf.

world environment, combined with a lack of resources, results in an incomplete training experience. Therefore, it is important to employ scientific approaches to inform the design of exercises. When real-life incidents occur, it is important to collect and critically examine performance data, and to develop lessons learned about existing capabilities and capability needs which can be addressed by advances in science and technology.

Roles of Federal Science and Technology in Ensuring National Preparedness

Scientific capabilities described in the Nuclear/Radiological Incident Annex to the National Response Framework include atmospheric monitoring and predictive modeling capabilities, site characterization, environmental monitoring and cleanup, radioactive waste storage and disposal, environmental remediation, evaluation of potential public health impacts, and population decontamination.[20] The Federal Radiological Monitoring and Assessment Center (FRMAC), which coordinates and manages Federal monitoring and assessment in radiological incidents, and the Interagency Modeling and Atmospheric Assessment Center (IMAAC), which coordinates and disseminates atmospheric dispersion-modeling products, are key interagency organizations that emergency managers and government officials rely upon when making response-phase decisions. For U.S. nuclear reactor facilities, the NRC is mainly responsible for regulating their safety. During an event at a nuclear power plant facility, NRC is responsible to coordinate response actions and activities and to reduce the consequence of a radioactive substance release. In any nuclear or radiologic event in the United States, whether accidental or adversarial, other agencies, such as CDC, multiple entities within DHS, DTRA, EPA, FDA, FEMA, FBI, HHS, USDA, and NOAA, provide capabilities necessary to monitor, and provide capabilities, resources, and tools, to address impacts on human health, agriculture, the environment, food supplies, and animal health.

Preparedness Science and Technology Capability Needs

Nuclear and radiological material monitoring and detection, atmospheric transport and dispersion modeling, and sensor technology research and development are essential science and technology investments for the delivery of several prevention and protection core capabilities: screening, search, and detection; interdiction and disruption; and risk management. Science and technology assets and programs support response mission area capabilities that focus on protecting life and public safety during an incident. These assets and programs provide products and services that aim to characterize and communicate health and environmental risks posed by contamination, support the development of management guidelines and protocols for handling contaminated waste and debris, and provide laboratory and analytical facilities needed to characterize the potential exposure to affected populations and emergency management officials when responding to an incident. The specific response phase roles and responsibilities of Federal agencies are described in detail in the Nuclear/Radiological Incident Annex to the National Response Framework[21]. Other longer-term recovery capabilities are provided by the all-hazards Recovery Support Functions detailed in the National Disaster Recovery Framework. [22]

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[20] FEMA, *National Response Framework*, "Nuclear/Radiological Incident Annex," http://www.fema.gov/pdf/emergency/nrf/nrf_nuclearradiologicalincidentannex.pdf.

[21] FEMA, *National Response Framework*, "Nuclear/Radiological Incident Annex," http://www.fema.gov/pdf/emergency/nrf/nrf_nuclearradiologicalincidentannex.pdf.

[22] FEMA, *National Disaster Recovery Framework*, http://www.fema.gov/pdf/recoveryframework/ndrf.pdf.

Geological Hazards

The *Strategic National Risk Assessment in Support of PPD-8* identifies earthquakes, tsunamis, and volcanic eruptions as geological hazards. The Geological Hazard Team of the NPST Task Force included landslides and coastal and submarine processes (e.g., underwater landslides that may induce tsunamis; subsidence on rivers and shorelines undermines structures and critical infrastructure) because they are significant hazards that are studied by geoscientists and supported by agency science and technology units. Geologic events pose threats to human life and property through physical and chemical processes such as ground shaking and displacement, flooding, rapid soil liquefaction, lava flow, ash fall, and release of noxious gases.

Science and technology investments that support geological hazard preparedness and risk reduction include: advancing the knowledge of how geologic phenomena behave; understanding the mode and likelihood that geologic phenomena may expose communities or infrastructure to potential damage; tracking geological behavior through the use of Earth observations; forecasting potential damage by means of modeling; and developing products that characterize and communicate the risks posed by geologic hazards. These investments provide the foundational knowledge and capability necessary to develop early warning systems to aid evacuations, to design infrastructure systems that withstand the impacts of geologic events, and to decide when to deploy resources to coordinate response and recovery actions.

Hazard assessments are a scientific product that aids preparedness for geologic hazards. The value of science and technology investments in hazard assessments is seen in the response to emerging threats such as human-induced seismic events. The central United States experienced close to 900 earthquakes of magnitude 3.0 or greater per year during 1973–2008. This annual rate increased in recent years to over 2,000 earthquakes of magnitude 3.0 and greater occurring from 2009–2015, several of which have been damaging. Recently published assessments of emerging geologic hazards like induced seismic events provide information that enable government officials to make evidence-based policy or regulatory decisions to mitigate the risk, such as through reduced wastewater injection rates. For example, scientific hazard assessments of induced seismicity and linkages to wastewater injection have led to a moratorium on new drilling of disposal wells in parts of Arkansas susceptible to injection-induced seismicity. Further, the Railroad Commission of Texas is issuing new rules to regulate injection well permits and operation based on seismic risk.[23]

Roles of Federal Science and Technology in Ensuring National Preparedness

Federal efforts to foster preparedness for geologic hazards focus on improving fundamental understanding of geologic phenomena, and translating that knowledge into alerts and warnings or hazard and risk information products that describe expected levels of geologic activity over some time period. Several Federal agencies with diverse missions provide this scientific expertise and capabilities. For example, for volcanic hazards, new ash fall and other warning capabilities are beginning to be implemented and tested through investments made by the U.S. Geological Survey (USGS). Further capabilities are provided by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory, which maintains atmospheric transport and dispersion modeling capabilities to track volcanic ash. In the event of a volcanic eruption, these capabilities are necessary to provide information to officials to maintain public safety and ensure the safety of commercial activities, such as domestic and international aviation. Another important example of this collaboration relates to tsunami. USGS seismic sensors and analyses provide critical support to NOAA's Tsunami Warning Centers, which use this information to estimate the tsunami source, run propagation models, and ultimately deliver public

[23] Richard Perez-Pena, "U.S. Maps Pinpoint Earthquakes Linked to Quest for Oil and Gas," *New York Times*, April 23, 2015.

tsunami warnings. For earthquakes, the National Seismic Hazard Model, which was developed at USGS with investments from the National Earthquake Hazards Reduction Program (NEHRP), supports the design of earthquake-resilient building codes. Similarly, the National Tsunami Hazard Mitigation Program (NTHMP) member states and territories, through Federal grant investments, have developed inundation and evacuation maps to improve the tsunami resilience of at-risk coastlines. NASA contributes to loss reduction for multiple hazards by providing several types of satellite and airborne imaging for hazard monitoring and post-disaster assessment, response and recovery, and contributes both research and data to efforts of the other mission agencies. In addition, NSF, which plays a special stewardship role overseeing the nation's fundamental research capabilities, supports research and observational facilities in the geological hazards domain.

Preparedness Science and Technology Capability Needs

Opportunities for science and technology to support preparedness capabilities primarily exist in the areas of mitigation and response. Before, during, and after a geologic event, science and technology experts and tools aid public officials and the public by providing, for example:

- Risk assessments and forecasts, including hazard probability maps that inform planning and local and State decisions on building and infrastructure design codes that can withstand expected levels of geologic activity;
- Monitoring and modeling infrastructure, including remote Earth observation tools – like synthetic aperture radar (SAR), which detects ground deformations – as well as ground-based sensors that can be rapidly deployed during an event, to provide situational awareness to officials, emergency responders, and communities about impending or active earthquakes, volcanic eruptions, and landslides.
- Public communication, including educational outreach, that inform communities on relevant investments, such as building upgrades, and inform individuals on actions they can take to protect life or reduce injury during a geologic event.

Preparedness capabilities contribute to products and services developed to improve timely and accurate geologic hazard forecasts and warnings. For example, warnings that describe the timing and potential impacts of incoming waves of a tsunami generated by a large earthquake are essential for emergency managers to prioritize evacuations. These capabilities can also be used as input to educational products for the public. Training and outreach sessions, such as the international tsunami exercises "Pacific Wave" and "CARIBE Wave" and the national "Great ShakeOut" earthquake drills (which also includes tsunami-evacuation drills where applicable), provide information to individuals, businesses, and communities on preparedness actions that can be taken to protect against loss and damage and accelerate recovery.

Research that aim to improve understanding of geologic hazard phenomena is also used to produce hazard assessments for mitigation. Some of these assessments are based on the same measurement, monitoring, and modeling research infrastructure used for response-related capabilities, and they are used to inform how structures and infrastructure can be designed or hardened to withstand various levels of geologic hazard, to delineate "the footprint" of the hazard phenomena on the landscape as evidenced by specific geologic deposits that are preserved in the geologic record; and to serve as a guide to the types of geologic hazards that have occurred in the past. Age dating of such deposits also helps to determine the recurrence rate of the geologic hazard that generated the characteristic deposits. Other assessments may be conducted with data-modeling capabilities: for example, quality 3D elevation data models support more accurate flood hazard maps, mitigate flood risk, identify potentially active faults, mitigate coastal erosion and storm surge impacts, identify landslide hazards, and save property and lives;

Meteorological Hazards

The meteorological hazards considered in this report are droughts, floods, hurricanes, tornados, wildfires, winter storms, and heat waves, as represented in the Department of Homeland Security (DHS) Strategic National Risk Assessment of December 2011.[24] From 1953 to 2014, severe storms, floods, and hurricanes represented nearly 80 percent of the major disaster declarations requested by State governors and approved by the President. Severe storms coupled with heavy precipitation and flooding are the most frequently cited hazard. Weather-based disasters impact all parts of the United States -- presenting significant challenges to state, local, and tribal residents, responders, and governments -- and impacts from climate change are expected to increase the intensity of meteorological hazard events throughout the country for years to come.

In addition, weather is considered a "threat multiplier" by those who are concerned with national security and resilience. Internationally, extreme weather and climate-scale meteorological trends can disrupt energy, infrastructure, water, and food supply systems, increasing competition for resources, worsening living conditions, and thereby potentially accelerating political and social instability. Weather can also multiply the potential for harm from technological and human-caused hazards. Wind, precipitation, and other meteorological conditions can greatly influence the trajectories and delivered concentrations of radiological and chemical releases.

The United States has long been committed to continuous improvement in science and technology to prepare for meteorological hazards and to ensure that scientific understanding is embedded in tools that individuals, businesses, and communities can use as they prepare for, respond to, and recover from severe weather events. Improvements in forecasting the location, timing, magnitude, and risks associated with weather events have improved the ability to prepare for those events. Related improvements in long-term, climate-scale forecasts provide a basis for decisions about design standards for buildings and infrastructure and how best to arrange public services where future vulnerabilities to severe and extreme weather exist.

Federal Government actions taken during and after Hurricane Sandy in 2012 illustrate the diversity of science and technology resources that support meteorological response. Prior to the storm's landfall, the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) forecasters provided real-time predictions of the track, intensity, and impacts of the storm. Staff scientists at the U.S. Geological Survey (USGS) augmented their monitoring networks, including the USGS stream-gauge network, to track storm surge and flooding during the event, and they used the enhanced data to model expected impacts to coastal beaches and dunes, identifying locations where storm forces could penetrate coastal barriers. Once the storm arrived, technical assets deployed by DHS, NOAA NWS, NGA, and NASA provided aerial photographic surveys and satellite & aerial remotely sensed imagery – including Synthetic Aperture Radar (SAR) and associated analytic products -- to help emergency managers prioritize actions and ensure safety during response activities, and aid in damage assessment. The U.S. Army Corps of Engineers (USACE) scientists and engineers modeled expected storm-surge flooding in New York City at high resolution to evaluate potential tunnel flooding and flew pre- and post-storm aerial light detection

[24] DHS, "The Strategic National Risk Assessment in Support of PPD 8: A Comprehensive Risk-Based Approach toward a Secure and Resilient Nation," https://www.dhs.gov/xlibrary/assets/rma-strategic-national-risk-assessment-ppd8.pdf.

and ranging (LIDAR) surveys to evaluate coastal impacts.

Roles of Federal Science and Technology in Ensuring National Preparedness

The National Preparedness Frameworks take an all-hazard approach to the roles and responsibilities of Federal agencies and their programs in supporting the core capabilities needed for five preparedness mission areas. Science and technology capabilities, by contrast, are often, though not always, hazard-specific. They also tend to pertain to multiple capabilities and mission areas. With regard to meteorological hazards and events, science and technology capabilities broadly fall into four of the five mission areas: protection, mitigation, response, and recovery. These capabilities generally support planning, public information and warnings, threat and hazard identification, risk and disaster resilience assessment, and situational assessment.

Federal science and technology investment for the preparedness for this report's meteorological hazards primarily resides in the executive branch Departments of Commerce (which includes NOAA's National Weather Service among other key offices) Defense, Homeland Security, Interior, Agriculture, Transportation, Energy, as well as NASA and EPA. Centers, laboratories and offices within these departments and agencies produce meteorological hazard science and technology. NOAA maintains the Office of the Federal Coordinator for Meteorology, which is an important Federal office dedicated to the interagency coordination of activities related to the development and delivery of meteorological services. In addition, NSF, which plays a special stewardship role overseeing the nation's fundamental research capabilities, supports research and observational facilities in the meteorological hazards domain.

Preparedness Science and Technology Capability Needs

The following examples describe how meteorological science and technology capabilities support the four preparedness mission areas mentioned above:

- With regard to the protection mission area, science and technology investments in weather forecasting, hydraulic and hydrologic analysis, and sustained Earth-observation capabilities support the characterization of the environment over short and long timescales. These data and information support public information and warnings, inform risk management decisions, and help with design of physical protective measures.
- With regard to the mitigation mission area, valuable technical capabilities include weather forecast products, risk and vulnerability assessments, and situational awareness products relevant to meteorological hazards (e.g., data on soil moisture related to drought risk and wind load information relevant to building design). All mitigation core capabilities described in the National Mitigation Framework are supported by Federal science and technology investments.
- With regard to the response and recovery mission areas, technical capabilities are derived from the application of observations, modeling, analysis, and information products that are key to providing accurate and timely situational assessments, and aid decisions on the application of all other response mission area capabilities (e.g., mass care services, public health, environmental response). Recovery mission area capabilities rely upon technical input derived from meteorological models, forecasts, and observations to assess damage and plan for the restoration of community services, ecosystem services, and infrastructure.

These capabilities rely on improvements in observations, environmental monitoring, and associated modeling of meteorological phenomena to enhance fundamental understanding of meteorological processes, identify sources of predictability, and improve predictions of weather and climate phenomena across timescales. Improvements are also needed in social science (e.g., decision science) to inform risk communication, decision making, and engineering for improved performance of operations and infrastructure.

Space Weather and Near-Earth Object Hazards

SPACE WEATHER

Space weather events are naturally occurring phenomena arising from solar emissions, including solar flares, solar energetic particles, and coronal mass ejections. All of these types of emissions are included in the Strategic National Risk Assessment definition of space weather hazards, and they were considered by the space hazards team. When such emissions interact with Earth, Earth's magnetic field, and the surrounding space, they have the potential to generate magnetic storms that disrupt electrical power systems; aircraft, satellite, and spacecraft operations; telecommunication systems; and position, navigation, and timing services. Critical infrastructure interdependencies, particularly electrical system interdependencies, increase the risks posed by space weather hazards, and action must be taken to prepare for, protect against, and mitigate these risks.

Science and technology investments to prepare for space weather hazards aim to improve observations, detection, and prediction capabilities in order to develop decision support services that connect the hazard to estimated impacts on vulnerable infrastructure and systems.

Engagement and coordination between the Federal Government, industry, and academia is essential to prepare for space weather hazards. Recent coordinated actions include replacing aging satellite assets, transitioning research models to space weather operations centers, proposing space weather standards for aviation, developing procedures for electrical grid operations during space weather events, and developing a plan for critical transformer replacement due to damage sustained in an event.

Space weather events occur regularly, often with measurable effects on critical infrastructure systems. Extreme events, while rare, have the potential to cause catastrophic damage to modern technology systems. The solar storm of 1859, which is known as the Carrington event, is one of the most severe space weather events on record. The event disrupted the long-range communication technology of the day, which was the electronic telegraph system, and caused the northern lights, which is a visible manifestation of space weather that typically occurs at higher latitudes, to appear in equatorial regions. Given the development of the modern, interconnected electric power grid and the proliferation of electronic technologies since 1859, the effect of a Carrington-level event today could be significantly more disruptive. Some researchers and engineers believe that a Carrington-level event today in North America could disrupt or damage components of the electric power grid, potentially leading to widespread and long-term power outages.[25, 26, 27] More recently, a March 1989 space weather event affected the Canadian Hydro-Quebec electric power grid. Although much smaller in scale compared to the Carrington event, the event still resulted in power loss for millions of customers in the Canadian province of Quebec. In late

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25 Lloyd's, "Solar Storm Risk to the North American Electric Grid," produced in association with Atmospheric and Environmental Research, Inc., 2013.

26 J. Kappenman, "Geomagnetic Storms and Their Impacts on the U.S. Power Grid," Technical Report Meta-R-319, Metatech Corp. January 2010.

27 J. S. Foster, E. Gjelde, W. R. Graham, R. J. Hermann, H. M. Kluepfel, R. L. Lawson, G. K. Soper, L. L. Wood, Jr., and J. B. Woodard, *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack*, Volume 1, Executive Report, 2004, http://www.empcommission.org/docs/empc_exec_rpt.pdf.

October 2003, multiple space weather events resulted in a host of issues with aircraft and satellites that disrupted operations for several weeks. At least 28 orbiting spacecraft were affected, one satellite was lost entirely, airline flights to polar regions were rerouted, and the FAA issued its first-ever alert for airplane passengers due to high radiation doses.[28] These events make it clear that modern technologies, both land-based and space-based, are vulnerable to space weather, and the 1859 Carrington event reminds us of the far-reaching effects of space weather events.

Roles of Federal Science and Technology in Ensuring National Preparedness

Key operation centers, such as the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center and the U.S. Air Force 557th Weather Wing, 2nd Weather Squadron, Space Weather Flight, provide the majority of today's operational forecast products and warnings to a broad user community spanning the public and private sectors. These centers provide the forecast and warning services that inform potentially vulnerable infrastructure owners and operators of elevated risks due to a coronal mass ejection. These services support the core capabilities of public information and warning, operational coordination, threat and hazard identification, infrastructure system support, and situational assessment.

In addition to these operational roles supporting core capabilities, Federal agencies such as the National Science Foundation (NSF) and USGS conduct fundamental and applied research to improve understanding of solar-terrestrial physics and development of new techniques for forecasting solar and geophysical disturbances. Federal agencies also provide support specifically for critical infrastructure support. Efforts include modeling and decision support tools to monitor, predict, and respond to effects on the electric grid and to the transportation infrastructure (e.g., aviation and rail).

Preparedness Science and Technology Capability Needs

Detecting significant space weather events, analyzing observations and model output, and providing decision support information require a portfolio of observations, research, and model development as well as advances in fundamental understanding of the nature of space weather hazards and the associated response of vulnerable systems. The 2015 Nationa*l Space Weather Strategy* and *National Space Weather Action Plan* describe many of the goals and specific actions required of the scientific community to prepare for space weather events. The national strategy defines six strategic goals for national preparedness related to near- and long-term space weather hazards: (1) establish benchmarks for space weather events; (2) enhance response and recovery capabilities; (3) improve protection and mitigation efforts; (4) improve assessment, modeling, and prediction of impacts on critical infrastructure; (5) improve space weather services through advancing understanding and forecasting; and (6) increase international cooperation. [29]

The Space Weather Action Plan (SWAP) describes specific objectives related to each of the strategic goals, and the required actions needed to achieve those objectives. Many of the priority actions for space weather hazard preparedness fall into forecasting-related capability development and implementation. These capabilities provide broad mission area support to the delivery of core protection, mitigation, and response capabilities. Accordingly, science and technology opportunities described in this report are consistent with the SWAP actions.

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[28] D. F. Webb and J. H. Allen, "Spacecraft and Ground Anomalies Related to the October-November 2003 Solar Activity," *Space Weather* 2, 2004, doi:10.1029/2004SW000075.

[29] National Science and Technology Council, *National Space Weather Strategy,* 2015. https://www.whitehouse.gov/sites/default/files/microsites/ostp/final_nationalspaceweatherstrategy_20151028.pdf.

NEAR EARTH OBJECTS

Asteroids and comets are examples of Near-Earth Objects (NEOs) and present a planetary hazard through their potential impact with Earth. Although the probability of a NEO impact are relatively low, the consequences of not being prepared if impact does occur may be high. The severity of potential consequences posed by NEOs merit potential inclusion in future versions of the Strategic National Risk Assessment.

Federal science and technology programs are responsible for detecting, tracking, and characterizing NEOs and for calculating the risk of a NEO colliding with Earth. NASA's NEO survey efforts that began in the 1970s have since stretched across the world with thousands of individual observations taken globally each night. More recent Federal science and technology efforts have taken direction from the 2010 National Space Policy, stating that the NASA Administrator shall "[p]ursue capabilities, in cooperation with other departments, agencies, and commercial partners, to detect, track, catalog, and characterize near Earth objects to reduce the risk of harm to humans from an unexpected impact on our planet and to identify potentially resource-rich planetary objects."[30] New capabilities being developed will support protection, mitigation, and response mission areas, and early efforts are underway to develop NEO impact-specific recovery capabilities. Current capabilities largely rely on a sustained observation program being responsible for detecting, characterizing, and tracking potential NEO threats; monitoring known NEOs, including artificial objects orbiting Earth; communicating potential threats to public safety and emergency response officials; and establishing operational response capabilities unique to NEO impacts.

Based upon current understanding of NEO impact risk, frequency is expected to be inversely proportional to the NEO's size. Large NEO impacts that pose a planetary risk are extremely rare, with an expected return interval of once in 100 million years. Smaller NEO impacts, such as from a 25-meter NEO, are expected to occur with a return interval of once in 100 years. The 20-meter NEO that exploded over a small town near Chelyabinsk, Russia, in 2013 created an airburst that damaged property and injured residents. Individuals watching the NEO entry reported sunburn or retinal injuries, and the associated shockwave resulted in building damage and flying debris that caused additional injuries.[31]

Roles of Federal Science and Technology in Ensuring National Preparedness

Programs such as NASA's Near-Earth Object Program and ground-based observatories funded by NSF provide both operational and research capabilities relating to the observation of asteroids and other objects in general. These observational efforts are combined with the efforts of the NASA Planetary Defense Coordination Office, which is responsible for detecting, tracking, and characterizing NEOs, and for issuing subsequent warning and impact analyses, public communication, and coordinating U.S. Government response activities.[32] These efforts will provide similar capabilities to those that the Department of Defense (DOD), particularly the U.S. Strategic Command and the U.S. Air Force, use to detect, track, and catalog all artificial objects orbiting Earth (i.e. satellites, spent rocket bodies, and debris), including capabilities to issue warnings and communications about potential impacts associated with

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30 EOP, *National Space Policy of the United States of America*, June 28, 2010, https://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf.

31 O. P. Popova, P. Jenniskens, V. Emel, A. Kartashova, E Biryukov, S. Khaibrakhmanov, and N. Hertkorn, "Chelyabinsk Airburst, Damage Assessment, Meteorite Recovery, and Characterization," *Science*, 342 (November 2013), 1069–1073, http://doi.org/10.1126/science.1242642.

32 Objects that come within 0.5 astronomical units of Earth, and size large enough to reach Earth's surface, or approximately 30-50 meters diameter.

reentry of those objects.

The recently formed Planetary Impact Emergency Response Working Group (PIERWG), which is co-chaired by NASA and the Federal Emergency Management Agency (FEMA), aims to establish a framework and process for deploying a wider-reaching preparedness effort for NEO hazards within the all-hazard framework adopted by the National Preparedness Goal. The PIERWG is proposed as a clearinghouse to understand the specific science that would inform recommendations for response efforts. Current research activities should aid efforts to inform the public of this particular hazard and how this scenario would be different from other natural disasters. For instance, due to exposure to The Weather Channel and public outreach by NOAA's National Hurricane Center, most Americans understand hurricane graphics. But, in the case of a potential asteroid impact, the "impact ellipse" maps used to predict possible impact areas are based on Monte Carlo simulation analysis and would not be immediately understood. Likely questions might be:

- What tools and methods have been used to determine where it will impact?
- What thresholds should be established to guide public policy on whether to try a deflection effort?
- Would there be less risk to just endure the impact?

Uniquely for a natural hazard, NEO impacts may, depending on the size of the NEO and length of warning time, be preventable. Therefore NASA is conducting several on-going research activities that are expected to enable in-space impact mitigation (object deflection or disruption) and on-ground preparedness and recovery mission areas. For example, the National Nuclear Security Administration and NASA maintain research activities that aim to develop and expand capabilities to deflect or disrupt NEOs before an Earth impact and model atmospheric entry and airburst effects. NOAA and DHS's Science and Technology Directorate conduct modeling to improve understanding of land and water impact effects and associated infrastructure impacts.

Preparedness Science and Technology Capability Needs

Roles supported by Federal science and technology investments primarily relate to providing information about situational awareness and hazard characterization. Based upon the National Response Framework structure and the associated core capabilities, current operational roles and responsibilities for NEO hazard preparedness fall into hazard identification, protection, mitigation, and response capabilities. Science and technology capabilities associated with NEO hazards relate to public information and warning, operational coordination, risk management, threat and hazard assessment, and situational assessment.

Because NEO impacts are infrequent, the Nation has limited experience in deploying significant operational assets to activate mission area capabilities needed to address them. In addition, little information and data are available about the population of potential asteroids or comets characterized as NEOs that pose a potential planetary threat. Existing science and technology investments are focused on developing capabilities to observe, track, and characterize potential hazards. Science and technology opportunities for NEO preparedness include supporting the following capabilities: (1) identification of threats; (2) supporting requirements for coordinating emergency response roles and responsibilities upon identification of potentially hazardous object impacts; (3) improvement in models to understand consequences of a NEO impact, including assessing vulnerability of terrestrial, sea-, and space-based assets, infrastructure, and populations; and (4) research into potential capabilities to deflect or disrupt NEOs that pose a threat. These four broad categories of preparedness capabilities cross-cut the six categories of science and technology priorities.