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Report to Congressional Requesters

March 2016

CRITICAL INFRASTRUCTURE PROTECTION

Federal Agencies Have Taken Actions to Address Electromagnetic Risks, but Opportunities Exist to Further Assess Risks and Strengthen Collaboration

GAO-16-243

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GAO Highlights

Highlights of GAO-16-243, a report to congressional requesters

Why GAO Did This Study

Electromagnetic risks caused by a man-made EMP or a naturally occurring solar weather event could have a significant impact on the nation's electric grid as well as other infrastructure sectors that depend on electricity, such as communications. These risks could lead to power outages over broad geographic areas for extended durations.

GAO was asked to review federal efforts to address electromagnetic risks to the electric grid. This report examines (1) the extent to which key federal agencies have taken action to address electromagnetic risks and how these actions align with the 2008 EMP Commission report recommendations, and (2) what additional opportunities exist to enhance federal efforts to address electromagnetic risks to the electric grid. GAO reviewed the EMP Commission report and federal program documents, and interviewed DHS, DOE, and FERC officials and relevant stakeholders who provided insights on key actions taken.

What GAO Recommends

GAO recommends that DHS identify internal roles to address electromagnetic risks, and collect additional risk inputs to further inform assessment efforts; that DHS and DOE collaborate to ensure critical electrical infrastructure assets are identified; and engage with industry stakeholders to identify and prioritize risk-management activities, such as research and development efforts, to address EMP risks to the grid. DHS and DOE concurred with our recommendations and identified planned actions to address the recommendations.

View GAO-16-243. For more information, contact Chris Currie at (404) 679-1875 or curriec@gao.gov.

What GAO Found

Key federal agencies have taken various actions to address electromagnetic risks to the electric grid, and some actions align with the recommendations made in 2008 by the Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack (EMP Commission). Since 2008, the Department of Homeland Security (DHS), the Department of Energy (DOE), and the Federal Energy Regulatory Commission (FERC) have taken actions such as establishing industry standards and federal guidelines, and completing EMP-related research reports. GAO found that their actions aligned with some of the EMP Commission recommendations related to the electric grid. For example, DHS developed EMP protection guidelines to help federal agencies and industry identify options for safeguarding critical communication equipment and control systems from an EMP attack. Further, agency actions and EMP Commission recommendations generally align with DHS and DOE critical infrastructure responsibilities, such as assessing risks and identifying key assets.

Additional opportunities exist to enhance federal efforts to address electromagnetic risks to the electric grid. Specifically, DHS has not identified internal roles and responsibilities for addressing electromagnetic risks, which has led to limited awareness of related activities within the department and reduced opportunity for coordination with external partners. Doing so could provide additional awareness of related activities and help ensure more effective collaboration with other federal agencies and industry stakeholders. Moreover, although DHS components have independently conducted some efforts to assess electromagnetic risks, DHS has not fully leveraged opportunities to collect key risk inputs—namely threat, vulnerability, and consequence information—to inform comprehensive risk assessments of electromagnetic events. Within DHS, there is recognition that space weather and power grid failure are significant risk events, which DHS officials have determined pose great risk to the security of the nation. Better collection of risk inputs, including additional leveraging of information available from stakeholders, could help to further inform DHS assessment of these risks. DHS and DOE also did not report taking any actions to identify critical electrical infrastructure assets, as called for in the National Infrastructure Protection Plan. Although FERC conducted a related effort in 2013, DHS and DOE were not involved and have unique knowledge and expertise that could be utilized to better ensure that key assets are adequately identified and all applicable elements of criticality are considered. Finally, DHS and DOE, in conjunction with industry, have not established a coordinated approach to identifying and implementing key risk management activities to address EMP risks. Such activities include identifying and prioritizing key research and development efforts, and evaluating potential mitigation options, including the cost-effectiveness of specific protective equipment. Enhanced coordination to determine key research priorities could help address some identified research gaps and may help alleviate concerns voiced by industry regarding the costs and potential adverse consequences on grid reliability that may be caused by implementation of such equipment.

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Abbreviations

CS&C	Office of Cybersecurity and Communications
DHS	Department of Homeland Security
DOD	Department of Defense
DOE	Department of Energy
EMP	electromagnetic pulse
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
GIC	geomagnetic induced current
GMD	geomagnetic disturbance
HEMP	high-altitude electromagnetic pulse
HSNRC	Homeland Security National Risk Characterization
I&A	Office of Intelligence and Analysis
INL	Idaho National Laboratory
IP	Office of Infrastructure Protection
IST	Infrastructure Survey Tool
NASA	National Aeronautics and Space Administration
NCC	National Coordinating Center for Communications
NERC	North American Electric Reliability Corporation
NIPP	National Infrastructure Protection Plan
NOAA	National Oceanic and Atmospheric Administration
NPPD	National Protection and Programs Directorate
ORNL	Oak Ridge National Laboratory
OSTP	Office of Science and Technology Policy
PPD	Presidential Policy Directive
QHSR	Quadrennial Homeland Security Review
RRAP	Regional Resiliency Assessment Program
SCADA	Supervisory Control and Data Acquisition
SNRA	Strategic National Risk Assessment
S&T	Science and Technology Directorate
USGS	U.S. Geological Survey

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U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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Congressional Requesters

An electromagnetic pulse (EMP) or solar weather event could have a debilitating impact on critical electrical infrastructure and communications systems, as well as other key assets and infrastructure that depend on electric utilities for power. EMP and solar weather events could potentially lead to power outages over broad geographic areas, some of which could last for an extended duration. Experts have also reported that long-term power outages could result in significant economic disruption and adverse impacts to public health and safety. Addressing these events necessitates effective collaboration among multiple government agencies and industry partners, and no single federal program or entity has sole responsibility for addressing electromagnetic threats. However, the National Infrastructure Protection Plan (NIPP) outlines the roles and responsibilities of the Department of Homeland Security (DHS) and applicable sector-specific agencies for each of the 16 critical infrastructure sectors.[1] DHS has the lead role in coordinating the overall federal effort to promote the security and resilience of the nation's critical infrastructure, and the Department of Energy (DOE)—as the sector-specific agency for the energy sector, which includes critical electrical infrastructure—shares responsibility with DHS.

[1]See DHS, *National Infrastructure Protection Plan, Partnering for Critical Infrastructure Security and Resilience* (Washington, D.C.: December 2013). Sector-specific agencies are the federal departments and agencies responsible for providing institutional knowledge and specialized expertise, as well as leading, facilitating, or supporting the security and resilience programs and associated activities of their designated critical infrastructure sector in the all- hazards environment. Presidential Policy Directive-21, *Critical Infrastructure Security and Resilience* (Feb. 12, 2013) (PPD-21) identifies the 16 critical infrastructure sectors and the sector-specific agencies.

In April 2008, the Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack (EMP Commission)[2] issued a report that included over 90 recommendations addressing the preparation for, and protection and recovery from, a possible EMP attack against U.S. critical infrastructure.[3] The majority of these recommendations were made to DHS and to DOE. According to the 2008 EMP Commission report, the nine commission members, nominated by the Secretary of Defense and the Federal Emergency Management Agency (FEMA) Administrator, provided a wide range of experience—including senior management experience in both civilian and military agencies, National Laboratories, and in the corporate sector.[4] Their expertise included management and operation of national infrastructures as well as technical expertise in the design of nuclear weapons, among other areas.

In July 2015, we testified before the Senate Homeland Security and Governmental Affairs Committee and reported preliminary findings

[2]Established pursuant to the National Defense Authorization Act for fiscal year 2001, the EMP Commission was responsible for assessing the following: 1) the nature and magnitude of potential high-altitude EMP threats to the United States; 2) the vulnerability of U.S. military and civilian systems to an EMP attack in terms of emergency preparedness; 3) the capability of the United States to repair and recover from damage inflicted by an EMP attack; and 4) the feasibility and cost of hardening selected military and civilian systems against EMP attack. See Pub. L. No. 106-398, §§ 1401-09, 114 Stat. 1654, 1654A-345-348 (2000). See also Pub. L. No. 109-163, § 1052, 119 Stat. 3136, 3434-35 (2006) (reestablishing the EMP Commission to continue its efforts to monitor, investigate, make recommendations, and report to Congress on the evolving threat to the United States in the event of an EMP attack resulting from the detonation of a nuclear weapon or weapons at high altitude); and Pub. L. No. 110-181, Div. A, § 1075 122 Stat. 3, 333 (2008) (providing, among other things, that the EMP Commission and the Secretary of Homeland Security shall jointly ensure that the work of the EMP Commission with respect to EMP attack on electricity infrastructure, and protection against such attack, is coordinated with DHS efforts on such matters). The National Defense Authorization Act for Fiscal Year 2016 once again reestablishes the EMP Commission but with an expanded purpose that includes the evolving threat from, among other things, nonnuclear and naturally occurring EMP. See Pub. L. No. 114-92, § 1089, 129 Stat. 726, 1015-16 (2015).

[3]While the commission did not specifically identify the total number of recommendations, our analysis identified over 90 recommendations, which included key recommendations and related subareas across 10 critical infrastructure sectors, including electric power, telecommunications, and emergency services, among others.

[4]See Pub. L. No. 106-398, § 1401, 114 Stat. at 1654A-345-46 (describing, among other things, the composition and qualifications of the commission's membership).

regarding DHS's efforts to address electromagnetic threats to the grid.[5] As 7 years have passed since the issuance of the 2008 commission report, you asked us to review actions taken by key federal agencies, such as DHS and DOE, to address electromagnetic risks. Our objectives were to determine (1) the extent to which key federal agencies have taken actions to address electromagnetic risks to the electric grid, including how these actions align with selected recommendations from the 2008 EMP Commission report and (2) the extent to which additional opportunities, if any, exist to enhance federal efforts in addressing those risks to the electric grid.

To address our first objective, we reviewed DHS, DOE, and Federal Energy Regulatory Commission (FERC) program documents, research reports, applicable risk assessments, and other supporting documentation such as program briefings, strategy planning efforts, and after action reports to identify actions these entities have taken to address electromagnetic risks to the grid since the EMP Commission issued its report in 2008.[6] We also interviewed knowledgeable federal agency officials to confirm our understanding of how their related actions address electromagnetic risks to the electric grid. We focused our efforts on the electric grid because of its foundational significance in providing electric power to other key critical infrastructures, such as communications, transportation, banking, and finance and its recognized vulnerability to electromagnetic risks. To determine how DHS and DOE actions align with the 2008 EMP Commission report recommendations, we reviewed EMP Commission information and recommendations related to the electric grid, as well as applicable laws, policies, and directives related to DHS's and DOE's critical infrastructure protection responsibilities. We reviewed descriptions of each of the actions that DHS and DOE identified to us and made an initial determination of how their actions aligned with the commission recommendations. Internally, we independently verified the initial alignment decisions and general descriptions of DHS's and DOE's actions and subsequently had them validated by DHS. To determine how

[5]GAO, *Critical Infrastructure Protection: Preliminary Observations on DHS Efforts to Address Electromagnetic Threats to the Electric Grid*, GAO-15-692T (Washington, D.C.: July 22, 2015).

[6]FERC is an independent federal agency that regulates the interstate transmission of electricity, natural gas, and oil, and has authority to approve reliability standards proposed by the North American Electric Reliability Corporation (NERC), among other responsibilities. See 42 U.S.C. § 7172.

FERC's actions align with the 2008 EMP Commission report recommendations, we interviewed FERC officials and reviewed documentation regarding FERC's rulemaking on geomagnetic disturbance (GMD) reliability standards.

To address the second objective, we interviewed multiple officials from DHS components and other principal federal agencies addressing electromagnetic risks, as well as industry associations, subject-matter experts from research organizations, product manufacturers, and electric utility operators to confirm our understanding of their additional efforts. Specifically, we met with DHS officials from the National Protection and Programs Directorate (NPPD), the Science and Technology Directorate (S&T), Office of Intelligence and Analysis (I&A), DHS Office of Policy, and the Federal Emergency Management Agency (FEMA), as well as federal officials from DOE, FERC, the Department of Defense (DOD), and the National Oceanic and Atmospheric Administration (NOAA). We also met with industry association officials from the American Public Power Association and Edison Electric Institute, subject-matter experts from the Electric Power Research Institute and Metatech Corporation, and product manufacturers and utility operators from ABB Group, EMPrimus, Dominion Power, and PJM Interconnection. We identified the nonfederal entities we interviewed—through discussions with federal officials and our background research—as key stakeholders and subject-matter experts within the electric power industry. While these interviews are not generalizable to the entire industry, they provided valuable insights on key issues and applicable coordination activities with the federal government to address electromagnetic risks. In addition, we reviewed program documentation and applicable reports, briefings, and other materials related to DHS's risk assessment and mitigation efforts, including department-wide risk assessments, such as the Strategic National Risk Assessment and the Homeland Security National Risk Characterization process to better understand the department's overall efforts to address electromagnetic risks to the electric grid. We also reviewed key strategy and planning documentation, including the NIPP, the Energy Sector-Specific Plan, and the National Space Weather

Strategy and Action Plan.[7] We compared the actions DHS and DOE took against key risk-management criteria contained in the NIPP and Energy Sector-Specific Plan, as well as applicable internal control standards.[8] Lastly, we reviewed relevant reports by federal agencies and industry stakeholders to identify findings related to electromagnetic research and development needs, and to assess the extent to which additional risk management activities or collaboration could be beneficial.[9] We assessed the methodologies used in the relevant reports and determined them to be sufficient for the purposes of this report.

We conducted this performance audit from November 2014 to March 2016, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

According to experts, a nuclear EMP is the burst of electromagnetic radiation resulting from the detonation of a nuclear device, which can disrupt or destroy electronic equipment. Nonnuclear EMP weapons can also be designed to intentionally disrupt electronics, but these generally

[7]Developed by DHS, the NIPP is a comprehensive risk management framework that defines critical infrastructure protection roles and responsibilities for all levels of government, private industry, and other sector partners. As the sector-specific agency responsible for the energy sector, DOE develops and implements the Energy Sector-Specific Plan, which is an annex to the NIPP and serves as the framework for developing and implementing effective protective measures. See DHS, *Energy Sector-Specific Plan: An Annex to the National infrastructure Protection Plan* (Washington, D.C.: 2010). See also White House, *National Space Weather Strategy* (Washington, D.C.: October 2015) and *National Space Weather Action Plan* (Washington, D.C.: October 2015).

[8]GAO, *Standards for Internal Control in the Federal Government*, GAO/AIMD-00-21.3.1 (Washington, D.C.: November 1999).

[9]GAO, *Managing for Results: Key Considerations for Implementing Interagency Collaborative Mechanisms*, GAO-12-1022 (Washington, D.C.: Sept. 27, 2012). As part of its work on interagency collaboration, we conducted a literature review, interviewed 13 academic and practitioner experts in the field of collaboration, and reviewed their work. We also conducted a detailed analysis of 45 GAO reports, published between 2005 and 2012.

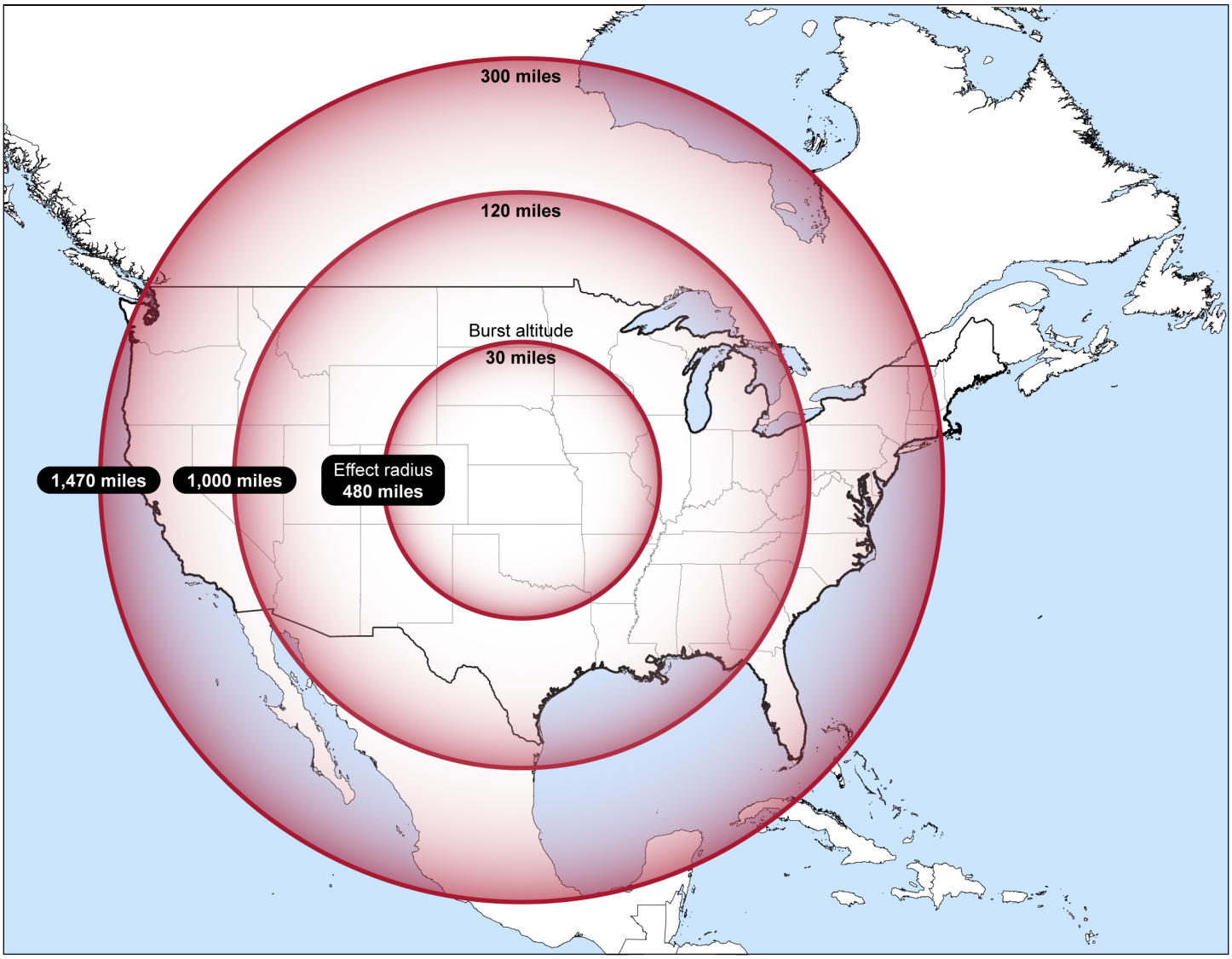
have short range and are not a threat to multiple assets.[10] The threat focused on primarily by the EMP Commission, and specifically addressed in this report, is the high-altitude EMP (HEMP). A HEMP event is caused by the detonation of a nuclear device above the atmosphere, from about 40 to 400 kilometers (approximately 25 to 250 miles) above the earth's surface.[11] A HEMP attack is not intended to cause direct physical impacts at the earth's surface, such as injury or damage directly from heat, blast, or radiation, but instead creates an intense electromagnetic pulse that can disrupt computers and damage electronics and insulators, and could cause significant damage to critical electrical infrastructure, such as transformers. The components of EMP—commonly identified as E1, E2, and E3—can cause disruption and damage to electronic systems and electrical infrastructure. For example, the E1 component, or fast pulse, primarily disrupts or damages electronic-based control systems, sensors, computers, and similar devices, but may also adversely affect long-line electrical systems; the E2 component, similar to lightning, has the similar ability to impair or destroy control features that are not protected from lightning; and the E3 component is a subsequent, slower-rising, longer-duration pulse that creates disruptive currents in transmission lines, which causes grid instability and increases heat in transformers.[12] If the E3 pulse is high enough and long enough it can result in grid collapse and potentially damage transformers.

[10]Non-nuclear EMP, in this context, is intense electromagnetic fields generated by high-power generators, which are directed to a target by an antenna. Non-nuclear EMP can be used for intentional electromagnetic interference, which is defined as intentional malicious generation of electromagnetic energy introducing noise or signals into electric and electronic systems, thus disrupting, confusing or damaging these systems for terrorist or criminal purposes.

[11]The higher the altitude and the larger the yield of the nuclear device, the greater is the radius of EMP effect (see fig. 1 for an illustrative example). A *source region EMP* (in this context) is an electromagnetic pulse created when a nuclear weapon detonates at low altitude (surface or near-surface detonation). The electromagnetic field is large compared to that from HEMP but it affects a smaller geographic area.

[12]According to the 2008 EMP Commission report, the electrical power system has existing protective measures for lightning, which are probably adequate to help protect against E2 effects. However, the report notes that system components damaged by the preceding E1 pulse may be at increased risk of subsequent E2 impacts.

Figure 1: Example of Estimated Impact Area of High-Altitude Electromagnetic Pulse, by Height of Burst



Source: Gary Smith, "Electromagnetic Pulse Threats," Testimony before the House Committee on National Security (July 16, 1997); MapInfo (map). | GAO-16-243

In addition to manmade EMPs, naturally occurring solar weather events of sufficient intensity can also cause electromagnetic impacts similar to the E3 pulse that can adversely affect components of the commercial electric grid, as well as other infrastructure such as satellites and undersea cables. The resulting impact of solar weather is commonly referred to as a geomagnetic disturbance (GMD).[13] In 1989, a GMD caused wide-scale impacts on the Hydro-Quebec power system in Canada which caused this regional electric grid to collapse within 92 seconds and left 6 million customers without power for up to 9 hours. See appendix I for additional information on GMD events. See table 1 for an overview of electromagnetic threats and their primary effects.

Table 1: Overview of Electromagnetic Threats and Primary Effects

Threat	Primary effects	Susceptible systems
High-altitude electromagnetic pulse (HEMP)	Fast pulse E1	Long-line and short-line electrical and electronic systems
	Slow pulse E3	Long-line network systems including electric power grid, terrestrial and undersea communication lines, pipelines
Space weather	Geomagnetic disturbance (Similar to slow pulse E3)	Long-line network systems including electric power grid, terrestrial and undersea communication lines, pipelines

Source: Dr. George Baker. | GAO-16-243

Note: Data are from testimony before the House Committee on National Security and the House Subcommittee on the Interior, Committee on Oversight and Government Reform (May 13, 2015).

As noted in Presidential Policy Directive 21 (PPD-21), the energy and communications sectors are uniquely critical due to the enabling functions they provide to other critical infrastructure sectors.[14] The U.S. electric power delivery system is a highly complex network of substations and electric lines that transport electricity from generators to residential, commercial, and industrial consumers. The U.S. electric grid has three

[13]According to the NOAA Space Weather Prediction Center, larger GMD's are generally associated with solar coronal mass ejections, which are explosions of magnetic field and plasma from the sun's corona. A coronal mass ejection moves outward from the sun through solar wind to reach the earth within 18—96 hours.

[14]Presidential Policy Directive 21, *Critical Infrastructure Security and Resilience*.

main components: generation (creation of electricity), transmission (long haul transport of electricity), and distribution (shorter distances connecting the electricity to the consumer/end user). In November 2015, FERC reported that there are over 24,000 substations nationwide, connected by over 430,000 miles of transmission lines.[15]

Given the interdependency among infrastructure sectors, an EMP or major GMD event that disrupts the electric grid could also result in potential cascading impacts on fuel distribution, transportation systems, food and water supplies, and communications and equipment for emergency services, as well as other communication systems that utilize the civilian electrical infrastructure. PPD-21 also recognizes that DHS has numerous responsibilities to protect critical infrastructure, including such things as analyzing threats to, vulnerabilities of, and potential consequences from all hazards on critical infrastructure.

Within DHS, NPPD is responsible for working with public and industry infrastructure partners, and leads the coordinated national effort to mitigate risk to the nation's infrastructure through the development and implementation of the infrastructure protection program. NPPD has two principal offices with responsibilities to facilitate protection of critical infrastructure that could be at risk from EMP and GMD events—the Office of Infrastructure Protection (IP) and the Office of Cybersecurity and Communications (CS&C).[16] In addition, FEMA and S&T have roles related to addressing potential impacts to the electric grid, which could

[15]This figure accounts for substations and associated transmission lines of 100 kilovolts and above.

[16]Within CS&C, the National Coordinating Center for Communications (NCC), (a legacy component of the National Communications System), leads the federal government's analysis of EMP effects on communications, information, and control systems, to fulfill EMP-related responsibilities in accordance with Title 47, Part 215, of the Code of Federal Regulations. See, for example, 47 C.F.R. § 215.2 (identifying the National Communications System as the focal point within the federal government for all EMP technical data and studies concerning telecommunications and responsible for providing such data and the results of such studies to all appropriate agencies requesting them).

include EMP and GMD threats. The offices of Cyber and Infrastructure Analysis and I&A also help support related departmental activities.[17]

DOE also has a significant role as the sector-specific agency for the energy sector, which includes critical infrastructure and key resources related to electricity. For example, DOE is responsible for developing an Energy Sector-Specific Plan—in collaboration with other stakeholders, including DHS and energy sector owners and operators—that applies the NIPP risk management model to critical infrastructure and key resources within the sector. Within DOE, the Office of Electricity Delivery and Energy Reliability leads national efforts to increase the security and reliability of the energy infrastructure and facilitate recovery from disruptions to the energy supply. Legislation enacted in December 2015 further authorizes the Secretary of Energy, upon submission by the president of a written directive or determination identifying an electrical grid emergency, to issue orders for emergency measures necessary to protect or restore the reliability of critical electric infrastructure or of defense critical infrastructure during such an emergency and establishes the Secretary of Energy as the lead sector-specific agency for cybersecurity for the energy sector.[18] DOE national laboratories also provide research support and technical expertise to federal and industry stakeholders regarding EMP and GMD impacts.

[17]In November 2015, the House of Representatives passed the Critical Infrastructure Protection Act, which if enacted would, among other things, direct that DHS, to the extent practicable, include the threat of EMP events in national planning frameworks and conduct outreach to educate owners and operators of critical infrastructure, emergency planners and emergency response providers at all levels of government, in consultation with relevant federal agencies and owners and operators of critical infrastructure; to the extent practicable, conduct research and development to mitigate the consequences of EMP events; and prepare a recommended strategy to protect and prepare the critical infrastructure of the U.S. against EMP events, including from acts of terrorism. See H.R. 1073, 114th Cong., 1st Sess. (2015) (referred to the Senate Committee on Homeland Security and Governmental Affairs on Nov. 17, 2015).

[18]See Fixing America's Surface Transportation Act, Pub. L. No. 114-94, div. F, § 61003, 129 Stat. 1312 (2015).

Other principal federal agencies working to address the threat of EMP and GMD include DOD and FERC, as well as NOAA, the U.S. Geological Survey (USGS), and the National Aeronautics and Space Administration (NASA).[19]

Electrical infrastructure is primarily operated by private industry, which owns approximately 85 percent of the nation's critical electrical infrastructure. Industry entities are represented, in part, through membership in industry associations such as the American Public Power Association, Edison Electric Institute, and National Rural Electric Cooperative Association. The North American Electric Reliability Corporation (NERC) also has authority to develop reliability standards to address the protection and improvement of the reliability and security of the electrical infrastructure.[20]

[19]NOAA operates the Space Weather Prediction Center—a 24/7 space weather monitoring facility that provides alerts and warnings to applicable federal entities, emergency-management personnel, and other affected parties, including operators of electric utilities. In addition to its national security and military responsibilities, DOD may also provide support to DHS following an EMP attack, including law enforcement, logistics, or other areas covered by the National Response Framework. NASA, in partnership with NOAA and the U.S. Air Force, launched the Deep Space Climate Observatory (DSCOVR) satellite in February 2015 to replace a research satellite monitoring solar storms and solar wind data. USGS, within the Department of Interior, is a science organization responsible for collecting, monitoring, and analyzing natural resource conditions, including the monitoring of variations in the earth's magnetic fields, which may be caused by severe solar weather events.

[20]NERC is a not-for-profit international regulatory organization whose mission is to ensure the reliability of the bulk-power system in North America and is subject to oversight by FERC and governmental authorities in Canada.

Key Federal Agencies Have Taken Various Actions to Address Electromagnetic Risks to the Grid; Some Actions Align with the 2008 EMP Commission Recommendations

Federal Agencies Have Taken Actions to Address Electromagnetic Risks to the Grid

DHS, DOE and FERC have taken various actions to address electromagnetic risks to the electric grid, which generally fall under four categories: (1) standards, guidelines, tools and demonstration projects; (2) research reports; (3) strategy development and planning; and (4) training and outreach.

Because federal agencies generally do not own electric grid infrastructure, federal actions to address GMD risks are more indirect through such things as developing standards and guidelines, and conducting research that could benefit electric grid owners and operators. Federal agencies have also been involved in strategy development and planning, as well as training and outreach efforts, as a means of preparing federal officials and others to respond to both EMP and GMD events, and enhancing knowledge about electromagnetic risks. For example, DHS S&T led the design and development of a prototype transformer that can be more easily transported to another location to help restore electric power in a timelier manner. DHS has also participated in various training and outreach events to enhance understanding of an EMP and GMD event. DOE's primary efforts include supporting research to enhance the understanding of the potential impacts to the electric grid from electromagnetic events. Overall, DHS and DOE have led most of the federal actions addressing protection and mitigation efforts. They were also the key participants, with the White House Office of Science and Technology Policy (OSTP) and NOAA, in developing the National Space Weather Strategy and Action Plan issued in October 2015 along with support from a variety of federal departments and agencies. Table 2 below summarizes the key actions taken by federal agencies—most of which were conducted since 2012—that help

to address electromagnetic risks. More detailed information on these individual activities is also included in appendix II.

Table 2: Summary of Key Federal Agencies' Actions Taken since 2008 to Address Electromagnetic Risks to the Electric Grid

Key federal agency action and description of effort	Lead entity	Supporting entities	Time frame
Standards, guidelines, tools and demonstration projects			
GMD reliability standards rulemaking process. The Federal Energy Regulatory Commission (FERC) directed a two-phase approach for the North American Electric Reliability Corporation (NERC) to develop Reliability Standards that address the impact of GMD on reliable operation of the bulk-power system.[a] As of November 2015, FERC was completing Phase 2 of the standard, which is to require initial and ongoing vulnerability assessments against a benchmark GMD event, among other actions.	FERC	Industry	2013-ongoing
Electromagnetic Pulse (EMP) protection guidelines.[b] Recommended guidelines available to federal agencies and other public service providers to identify options to help safeguard assets, such as critical equipment, facilities, and communication and data centers from various forms of EMP attacks.	Department of Homeland Security (DHS)—National Protection and Programs Directorate (NPPD)	Multiple federal agencies	2014—2015
Solar storm mitigation. A tool-development effort that is intended to enable more localized and precise geomagnetic induced current (GIC) forecast levels to provide utility owners and operators with timely and accurate information.	DHS—Science and Technology Directorate (S&T)	National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA)	2014—ongoing
Installation of magnetometers. Partnership to gather data on GIC and magnetic fields to help scientists validate models and develop more accurate estimations and modeling.	Department of Energy (DOE)—Office of Electricity Delivery and Energy Reliability	United States Geological Survey (USGS), NASA, Industry	2014—ongoing
Recovery Transformer (RecX). Demonstration program to develop an extra-high-voltage transformer prototype designed to reduce the time needed to transport, install, and energize a spare transformer.	DHS S&T	Industry	2009—2014
Resilient Electric Grid (REG).[c] Demonstration program to develop a fault-current-limiting high-temperature superconductor cable system and advance it to a commercially viable state. The cable system is intended to increase the flexibility and resiliency of the electric grid.	DHS S&T	Industry	2007—ongoing
Research reports			
Four reports addressing electromagnetic risks.[c] Authored by external industry experts to better understand the types and potential threats posed by electromagnetic risks, including EMP and GMD events.	DHS	Industry	2007—2014

Key federal agency action and description of effort	Lead entity	Supporting entities	Time frame
EMP Impacts on Transformers. Analyzed the potential impact of an EMP on extra-high-voltage transformers—focusing primarily on transformer equipment designs and identifying specific mitigation efforts such as blocking devices.	DHS	Industry	2010
Six reports addressing EMP impacts on the U.S. power grid. In January 2010, the Oak Ridge National Laboratory (ORNL) developed six technical reports for DOE, DHS, and FERC that examined EMP threats and potential impacts, and analyzed potential solutions for preventing and mitigating their effects.	ORNL	FERC, DHS, DOE	2010
Impacts of Severe Space Weather. Assessed the impacts of space weather on the electric grid, seeking to understand how previous solar storms have affected some electric grids, and what cost-effective mitigation options are available to protect the electric grid.	DHS	DOE, Industry, academia	2011
Pacific Northwest National Laboratory Study on Geomagnetic Storms and Long-Term Impact on Power Systems. Examined the potential impacts of a severe GIC event on the western U.S.-Canada power grid, referred to as the Western Interconnection.	DOE	DHS	2011
Large Power Transformer Study. Examined the characteristics and procurement of large power transformers, the availability of global and domestic suppliers, and assessed the potential risks facing these transformers, among others.	DOE	DHS, industry	2014
Sector Resilience Report: Electric Power Delivery. Summarized key electric power dependencies and interdependencies, such as communications, transportation, and other lifeline infrastructures.	DHS NPPD	DOE, FERC	2014
Idaho National Laboratory Study on EMP. Identified possible EMP protection and mitigation measures, and additional research areas to help assess the effects of EMP on the commercial bulk-power system.	DOE	Industry	2015
ORNL Study on the Susceptibility of Transformers to GMD. Examined the risks associated with solar weather events and their impact on electric power reliability.	DOE	Industry	2015—ongoing
Strategy development and planning			
National Space Weather Strategy and Action Plan. National strategy and action plan to address space weather threats, including efforts to establish benchmarks for space weather events, enhance response and recovery capabilities, improve protection and mitigation efforts, and to improve assessment, modeling, and prediction of impacts on critical infrastructure, among others.	White House Office of Science and Technology Policy (OSTP)	DHS NOAA, DOE and others	2014—2015
Power Outage Incident Annex. Plan to provide incident-specific information in support of the National Response and National Disaster Recovery Frameworks that outlines how the federal government plans to respond to and recover from loss of power resulting from deliberate acts of terrorism or natural disasters, such as a GMD event.	DHS—Federal Emergency Management Agency (FEMA)	DOE	2014—ongoing
National Transformer Strategy. National strategy to reduce the risk to grid reliability posed by the loss of critical large power transformers focused on: (1) understanding and mitigating current and future risks to transformers, (2) enhancing protection of transformers, and (3) ensuring transformer replacement equipment is available.	DOE	DHS, Industry	2015—ongoing

Key federal agency action and description of effort	Lead entity	Supporting entities	Time frame
Quadrennial Energy Review. Review focused on a broad range of challenges, including the potential impacts to the electric grid from EMP and GMD events.	White House OSTP	DOE and multiple federal agencies	2015
Training and outreach			
Secure Grid Exercise. Two-day training and security exercise that assessed the federal response to an extreme solar weather event.	DHS—NPPD and S&T	Multiple federal agencies industry	2011
GMD Technical Conference. Technical conference to discuss issues related to the reliability of the bulk-power system as affected by GMD events and how transformers would be impacted.	FERC	DHS, Industry, academia	2012
Briefings to Address Electromagnetic Risks. DHS has participated in multiple briefings before conferences and workshops that address electromagnetic risks, including EMP and GMD events.	DHS NPPD	Industry	2012—2015
GridEx II.[d] Industry-wide exercise, with key federal agencies, that assessed the readiness of the electric industry to respond to a physical or cyberattack on the bulk-power system.	Industry	DHS, DOE, Federal Bureau of Investigation	2013
Space Weather Workshops. Multiple training workshops that addressed space weather issues and their potential impact on the electric grid.	DOE, White House OSTP	DHS, Industry, academia	2015

Source: GAO analysis of DHS, DOE, and FERC actions addressing electromagnetic risks to the electric grid. | GAO-16-243

[a]FERC, Reliability Standards for Geomagnetic Disturbances, Order No. 779 (May 16, 2013).

[b]These guidelines were initially developed for use by the Federal Executive Branch Continuity Communications Managers Group but, according to DHS, have wide applicability to help protect any electronic equipment, facilities, and communications/data centers. These guidelines were made available in mid-2015 but, as of November 2015, have not been widely implemented by any federal agency.

[c]Although these actions were initiated in 2007, prior to the issuance of the 2008 EMP Commission report, we elected to include them in this table to be fully comprehensive given their close proximity to the commission report release.

[d]GridEx II's training scenarios did not specifically include electromagnetic threats but rather accounted for physical and cyberattacks. The effects of physical and cyberattacks, such as disrupted monitoring and controls systems and damaged infrastructure, are similar to effects posed by electromagnetic threats. Some of the lessons learned from these scenarios could be applied to planning for an EMP or GMD event.

Some Actions Taken by DHS and DOE Align with EMP Commission Recommendations

The actions recommended by the EMP Commission generally align with existing authorities and responsibilities of DHS and DOE relating to the protection of critical infrastructure, such as identifying key assets and analyzing risks, and as discussed above, DHS and DOE have taken actions to address some risks to the electric grid from electromagnetic

events.[21] Although DHS and DOE did not report that any of their actions were taken in response to the commission report, actions taken by both agencies have aligned with some of the recommendations. Specifically, the EMP Commission made seven recommendations related to the electric grid, most of which were directed to DHS and DOE. Of these seven recommendations, some of the actions that DHS and DOE took aligned with four of them. The seven EMP Commission recommendations related to the electric grid include the following:

1. conducting research to better understand infrastructure systems and interdependencies,
2. expanding activities to address the vulnerability of control systems,
3. identifying clear authority and responsibility to respond to an EMP attack,
4. engaging federal and industry entities to determine liabilities and funding,
5. establishing monitoring efforts and defining testing standards and metrics,
6. providing capabilities to help protect the electric grid from an EMP attack and recover as rapidly and effectively as possible, and
7. utilizing industry and governmental institutions to assure cost effective outcomes.

[21]Neither the statutes establishing the EMP Commission nor any subsequently enacted statutes require that a specific entity address a specific recommendation of the EMP Commission. Existing law and policy, however, have established requirements and responsibilities for federal entities, including DHS and DOE, which would support actions that are consistent with recommendations of the EMP Commission. For example, pursuant to title II of the Homeland Security Act of 2002, as amended, which establishes the department's authorities and responsibilities for securing the nation's critical infrastructure, DHS, is able to take action consistent with the recommendations. See, for example, 6 U.S.C. § 121 (establishing, among other things, the Secretary of Homeland Security's responsibilities relating to critical infrastructure protection and pursuant to which DHS developed the NIPP—a comprehensive national plan for securing the key resources and critical infrastructure of the United States, including power production, generation, and distribution systems). Further, PPD-21 and the NIPP identify DOE as the sector-specific agency for the energy sector, responsible for providing institutional knowledge and specialized expertise as well as leading, facilitating, or supporting the security and resilience programs and associated activities of the energy sector in the all-hazards environment. See also Pub. L. No. 114-94, div. F, § 61003, 129 Stat. 1312 (authorizing the Secretary of Energy, upon submission of a written directive or determination by the president identifying an electric grid emergency, to issue orders of emergency measures necessary to protect or restore the reliability of critical electric infrastructure or of defense critical infrastructure during such an emergency and establishing the Secretary of Energy as the lead sector-specific agency for cybersecurity for the energy sector).

DHS and DOE efforts to protect the electrical grid aligned with the first three recommendations noted above: conducting research to better understand the interdependencies of critical infrastructures, addressing the vulnerability of control systems to an EMP attack; and identifying responsibilities for responding to an EMP attack. They also aligned with the seventh recommendation, which includes 15 subparts, on utilizing industry and other governmental institutions to assure the most cost-effective outcomes.[22] For example, with respect to the recommendation on conducting research to better understand interdependencies of critical infrastructures, DHS's Sector Resilience Report: Electric Power Delivery includes some assessment of how various critical infrastructures—including the energy, communications, and transportation sectors, among others—are interdependent in maintaining operations.

With regard to the last multipart recommendation identified above, DHS and DOE took some actions that aligned with 5 of the 15 subparts of this recommendation. Some of the sub-parts include such efforts as developing national and regional restoration plans and assuring the availability of critical communication channels, among other efforts.[23] For example, DHS and DOE have actions underway to develop a Power Outage Incident Annex plan, which, according to DHS officials, is intended to provide incident-specific information regarding how the federal government plans to respond to and recover from a loss of power resulting from deliberate acts of terrorism or natural disasters, including an EMP or GMD event. In addition, a DHS entity developed EMP protection guidelines to help federal agencies and industry identify options for safeguarding critical communication equipment and control elements, such as Supervisory Control and Data Acquisition (SCADA) systems, from an EMP attack. For more detailed information regarding how identified federal actions align with these seven EMP Commission recommendations, see appendix III.

[22]App. III provides additional information on the seven EMP Commission recommendations, including the 15 subparts of recommendation 7 that we analyzed, and how DHS's actions align with four of them.

[23]DHS and DOE efforts aligned with three additional sub-parts, including (1) understanding system and network vulnerabilities, (2) assuring the availability of replacement equipment, and (3) conducting and simulating training exercises. See Appendix III for additional information regarding these efforts.

Additional Opportunities Exist for Federal Agencies to Identify Responsibilities, Assess Risks, and Strengthen Collaboration with Partners to Address Electromagnetic Risks

DHS Has Not Identified Roles and Responsibilities for Addressing Electromagnetic Risks

DHS has not clearly identified internal roles and responsibilities for addressing electromagnetic risks to the electric grid or communicated these to external federal and industry partners. While multiple DHS components and offices, including NPPD, FEMA, and S&T, have each conducted independent activities addressing electromagnetic risks to the electric grid, none have been tasked with lead responsibility for coordinating related activities within the department or with federal and industry stakeholders. As a result, we experienced ongoing challenges in identifying applicable DHS personnel and related departmental actions. For example, NPPD officials had difficulty identifying their specific roles and activities addressing electromagnetic risks to the electric grid, including efforts to collect or synthesize available risk information to provide input into department-wide risk assessments, such as the Homeland Security National Risk Characterization (HSNRC).[24] An official within NPPD/CS&C subsequently provided information to us regarding

[24]The HSNRC is a process in which senior DHS officials identify the most significant risks in DHS mission space for inclusion in the Quadrennial Homeland Security Review (QHSR) and department internal deliberations related to strategic posture to effectively and efficiently manage these risks. Every 4 years the Secretary is to complete a QHSR—a comprehensive examination of the homeland security strategy of the nation that is to include recommendations regarding the long-term strategy and priorities of the nation for homeland security and guidance on the programs, assets, capabilities, budget, policies and authorities of the department. See 6 U.S.C. § 347.

applicable activities conducted as part of his role leading efforts to help safeguard communications and information/control system capabilities in the event of EMP-related attacks or disasters. However, this official was initially identified to us by a non-DHS stakeholder and several other DHS entities that we interviewed regarding related efforts to address electromagnetic events lacked awareness of these activities. Further, DHS officials did not identify any DHS representatives or offices as having broader designated responsibility for performing key oversight or coordination roles regarding electromagnetic risks within DHS's overall infrastructure protection efforts, including activities intended to help address risks to the electrical grid.

Furthermore, industry representatives and other federal officials told us it is not clear who within DHS is responsible for addressing electromagnetic risks. One major industry association reported that although senior DHS officials participated in some collaborative bodies, such as the Electricity Subsector Coordinating Council, association representatives were unable to identify applicable DHS representatives at a working level because there was generally limited engagement with industry on these issues. In contrast, industry representatives stated that other key agencies, including DOE and FERC, have recognized offices and points of contact that were knowledgeable about electromagnetic issues of concern to the industry. Some industry officials also commented that having clarity about the DHS contacts was critical because DHS may be best positioned to serve as a liaison between them and DOD, which generally does not interact directly with industry on these issues. DOE officials also indicated that they did not know whom at DHS they should contact with regard to requesting related information, such as specific DHS research reports related to electromagnetic risks.

The Energy Sector-Specific Plan, which is guided by the NIPP, highlights the importance of identifying clear roles and responsibilities in achieving goals and objectives in security programs and emergency response planning. According to the Energy Sector-Specific Plan, stakeholders should clearly understand their respective roles and responsibilities, and plan to integrate their independently executed roles to achieve a common set of infrastructure protection outcomes. The 2008 EMP Commission report also recommended that DHS make clear its authority and responsibilities, as well as delineate the functioning interfaces with other governmental institutions, regarding EMP response efforts. Standards for

Internal Control in the Federal Government also cite this principle, stating the importance of ensuring that authority and responsibility are clearly assigned throughout the organization.[25]

According to officials within the DHS Office of Policy, addressing EMP risks has generally been a lower priority compared to other risks due to a combination of differing opinions on the likelihood of these events and their expectation that other federal agencies will be involved in responding to an electromagnetic event. For example, DHS officials noted that the nature of an EMP attack would constitute an "act of war" that would generally be included within DOD's mission. According to a senior DHS official, in the case of an EMP attack, it is likely that DOD would serve in the principal role of identifying our adversaries and taking applicable defensive or retaliatory actions; however, DHS and DOE are designated in the NIPP as the key federal entities responsible for efforts to protect the electric grid and recover from such an attack. DHS acknowledged this responsibility through its inclusion of EMP as a risk event in the 2015 update of the Strategic National Risk Assessment (SNRA), noting that damage from a deliberate attack on the grid could cause cascading impacts through other infrastructure systems, leading to economic disruption and the potential loss of life.[26]

The growing recognition of GMD as a significant risk event requiring the collaborative efforts of multiple federal agencies and industry stakeholders, to both prepare for and respond to, underscores the concerns that industry and other officials have raised about DHS's roles and responsibilities being clearly designated. In recent years, there has been a growing consensus among federal agencies, industry representatives, and independent researchers that a major GMD event could have significant impacts on the nation's electric grid and is probable enough to warrant federal action. For example, the recent National Space Weather Strategy and Action Plan, issued by the White House in October 2015, and ongoing development of the FERC GMD reliability standard further exemplify the growing recognition of GMD as a significant risk event that requires the collective expertise of multiple federal agencies,

[25]GAO/AIMD-00.21.3.1.

[26]To inform homeland security preparedness and resilience activities, the SNRA was conducted by DHS to evaluate known threats and hazards that have the potential to significantly impact the nation's homeland security.

as well as applicable industry partners. Designating internal roles and responsibilities within DHS regarding electromagnetic risks and communicating these to federal and industry partners could provide additional awareness of related activities and help ensure more effective and coordinated engagement with other federal agencies and industry stakeholders. The lack of clarity regarding DHS activities to address electromagnetic risks also increases the risk of potential duplication, overlap, or fragmentation within the department or across federal agencies. Officials from the DHS Office of Policy agreed that enhanced internal coordination among DHS entities could be beneficial and noted that there are actions currently underway to establish a Cyber, Infrastructure, and Resiliency group within the Office of Policy that could potentially facilitate further coordination efforts.

DHS and DOE Have Not Fully Addressed NIPP Requirement to Identify Key Electrical Infrastructure Assets

DHS and DOE have not taken actions to identify key electrical infrastructure assets as required given their respective critical infrastructure responsibilities under the NIPP. Specifically, as the two primary federal entities responsible for addressing key risk management objectives outlined in the NIPP related to the energy sector, DHS and DOE have important roles in determining the extent to which critical infrastructure assets are adequately identified and all applicable information is included in related analyses. For example, the NIPP explicitly states that to manage critical infrastructure risk effectively, partners must identify the assets, systems, and networks that are essential to their continued operation, considering associated dependencies and interdependencies of other infrastructure sectors. Further underscoring the importance of identifying critical electrical infrastructure assets, a DOE-sponsored November 2015 report developed by the Idaho National Laboratory also emphasizes the need to identify the grid facilities most critical to restoration and recovery to prioritize those assets which should be protected from EMP effects, citing that it is not feasible or cost-effective to protect all infrastructure assets across the electricity sector.[27] The 2008 EMP Commission report also specifically recommended that DHS and DOE prioritize nodes that are critical for the rapid recovery of other key sectors that rely upon electricity

[27]Idaho National Laboratory, *Strategies, Protections and Mitigations for the Electric Grid Effects from Electromagnetic Pulse* (November 2015).

to function, including those assets that must remain in service or be restored within hours of an EMP attack.

Notwithstanding these responsibilities, DHS and DOE did not report any actions taken to identify critical electrical infrastructure as part of risk management efforts for the energy sector. In response to our July 2015 testimony citing limited DHS activities to identify applicable electrical infrastructure assets, DHS stated that it was aware of a study that FERC had conducted that identified critical electrical substations and cited potential duplication as the reason for why DHS did not conduct any additional related efforts. The study, which FERC staff conducted in 2013, utilized network modeling to identify critical substations that FERC deemed significant enough to produce wide area outages across the U.S. power grid. According to FERC, the analysis was conducted, in part, to engage with owners and operators of those facilities to encourage the use of cyber and physical security best practices. While the FERC study provided data that could help inform further analysis of critical electrical infrastructure assets, FERC officials did not indicate their analysis was intended to address specific critical infrastructure responsibilities laid out in the NIPP.

Moreover, while FERC's study remains a positive step toward identifying select critical electrical infrastructure assets and addressing the EMP Commission's recommendations, it did not solicit participation from other federal agencies, including DHS and DOE. Given the significant critical infrastructure responsibilities and expertise of these agencies, this lack of participation may have diminished the potential robustness of the study. For example, DOE officials stated that the FERC study did not include an analysis of "blackstart" capability, which DOE officials believe may be another important element that should be considered when analyzing the criticality of electrical generation facilities. Blackstart capability indicates that a facility can resume operations without reliance on external power sources—a capability that is important in the aftermath of an electrical grid shutdown.[28] As the designated sector-specific agency, DOE has

[28]According to DOE officials, the vulnerability assessments called for in the forthcoming GMD reliability standard may also provide useful information to help determine which individual facilities may be critical given the requirement to identify potentially cascading effects to the bulk-power system. However, availability of this information will likely not occur for years because applicable entities have up to 60 months to complete these vulnerability assessments from the date of the final rule, which is not yet issued.

valuable expertise that could be useful based on their broad understanding of the bulk-power system, load factors, and specific asset characteristics that may be important to consider when determining the key elements of criticality that should be evaluated. In addition, DHS has specific expertise related to infrastructure dependencies that may be helpful to identify potential cascading impacts to other assets or systems resulting from electrical power outages that should be considered. Both DHS and DOE acknowledged that further collaborative efforts to assess critical electrical infrastructure could be beneficial; however, as of November 2015, neither DHS nor DOE have reported on any efforts to review the 2013 FERC study or collaborate further to jointly determine the key elements of criticality that they believe should be considered when evaluating the vast array of infrastructure assets constituting the U.S electric grid.[29]

The extensive size and scope of the electric power system necessitates collaboration among partners to ensure all individual expertise is effectively leveraged. For example, a senior FERC official testified in July 2015 that determining which of the substations nationwide are the most critical depends on the outcome one is pursuing.[30] The official noted that if grid stability and continuity is the desired outcome, then a relatively small set of substations (in the hundreds) could be considered critical; however, if preserving power supply to specific DOD or nuclear power station is the desired outcome, then an additional collection of substations would need to be included. The NIPP also notes that critical infrastructure partners may view criticality differently, based on their unique situations, operating models, and associated risks. Leveraging additional DHS and DOE expertise could help to ensure that all key elements of criticality are reflected in the results of FERC's study. Our work on federal agency

[29]In November 2015, FERC officials noted that they, along with DOE, provided input to DHS as part of efforts to identify critical electrical infrastructure assets pursuant to a February 12, 2013, executive order—*Improving Critical Infrastructure Cybersecurity*—that calls for a risk-based approach to identify—in consultation with Sector-Specific Agencies—critical infrastructure where a cybersecurity incident could reasonably result in catastrophic regional or national impacts. See Exec. Order No. 13636, *Improving Critical Infrastructure Cybersecurity,* 78 Fed. Reg. 11.739 (Feb, 19. 2013). As of November 2015, DHS and DOE had not identified any related efforts to identify critical electrical infrastructure assets.

[30]Joseph McClelland, testimony before the Senate Homeland Security and Governmental Affairs Committee hearing on Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse, 114th Cong., 1st sess., July 22, 2015.

collaboration supports this approach as well, noting that it is important to ensure that all of the relevant participants have been included in the collaborative effort.[31] Reviewing FERC's analysis and collaboratively determining the extent to which further assessment of critical electrical infrastructure may be needed would provide DHS and DOE an opportunity to contribute their unique knowledge and expertise, as well as better ensure that NIPP responsibilities are adequately addressed and all applicable elements of criticality are being considered.

DHS Has Not Fully Leveraged Existing Opportunities to Collect and Analyze Information on Electromagnetic Risks

Although DHS components have independently conducted some efforts to assess electromagnetic risks as identified above, the department has not fully leveraged available risk information or conducted a comprehensive analysis of these risks. Within the DHS Office of Policy, there is recognition that "space weather" and "power grid failure" are significant risk events, which DHS officials have determined pose great risk to the security of the nation.[32] However, these officials were unable to provide detailed information about the specific risk inputs—namely threat, vulnerability, and consequence information—that were used to assess how electromagnetic events compared to other risk events, or how they were used to inform DHS's applicable risk-management priorities. Further, officials within NPPD were unable to identify any specific actions taken or plans to systematically collect or analyze risk information regarding electromagnetic impacts to the electric grid as part of department-wide risk assessment efforts.[33]

Threat

According to experts, with respect to threat, there is a distinction between GMD and EMP regarding the ability to assess the probability of occurrence. In the case of GMD, space weather researchers currently

[31]GAO-12-1022.

[32]Officials in the DHS Office of Policy, which is responsible for executing the HSNRC process, stated that power grid failure serves as a reasonable proxy for EMP events when considering risks to include in the HSNRC.

[33]In December 2015, a DHS official within NPPD/CS&C/NCC identified that his office develops risk rankings incorporating information on electromagnetic events, and has briefed DHS officials and interagency partners on GMD and EMP risks. However, officials acknowledged these products were not fully vetted within the department and do not represent the formal views of DHS. We also did not identify any evidence showing that such information was utilized by DHS to inform principal risk assessments, such as the SNRA or HSNRC processes.

estimate a 6 to 12 percent chance that a Carrington class storm—a solar storm comparable in size to the largest on record—is likely to hit the earth in the next 10 years. The potential threat was recently illustrated in July 2012, when a Carrington class solar storm missed the earth by approximately 1 week, as the storm occurred on the far side of the sun facing away from the earth. In contrast, assessing the threat of an EMP attack remains more difficult given that analysts have to also account for human factors that can increase the level of uncertainty. Specifically, within the 2011 SNRA, DHS notes that incomplete knowledge of adversary capabilities and intent are sources of uncertainty regarding the frequency of some risks.

Although DHS components identified multiple efforts to support the collection of information regarding the threat of GMD, DHS identified a more limited range of efforts to collect threat information regarding potential EMP attacks.[34] I&A officials indicated that while there is no dedicated Center of Excellence within the Intelligence Community on EMP, there is subject-matter expertise available from analysts in related mission areas, such as chemical, biological, radiological, and nuclear issues. CS&C representatives further noted that a group of analysts in that office routinely monitor classified intelligence sources for EMP-related threat information, such as those available through the Joint Worldwide Intelligence Communications System. However, some additional opportunities may exist to leverage EMP threat information through I&A or direct collaboration with DOD, DOE, or other intelligence sources. For example, classified analytical products are available that address specific components of threat, such as assessment of EMP-related missile technologies, which could serve as an important input regarding adversary capabilities as part of DHS's overall assessment of electromagnetic threats. Although I&A officials have direct access to these materials, neither I&A nor NPPD officials identified efforts to specifically leverage this information as part of any department-wide risk-assessment efforts. However, I&A officials noted that they remain well-positioned to pursue additional collection and analysis of EMP-related information through the Intelligence Community, if tasked to do so by

[34]DHS is also currently collaborating with other federal agencies on GMD issues as part of implementing the National Space Weather Action Plan. As part of these efforts, designated federal agencies, including DHS are to support establishment of benchmarks for assessing potential geoelectric fields occurring as a result of a 1-in-100-year solar storm (with associated confidence intervals).

NPPD. Acquiring more comprehensive information on potential EMP threats may be helpful because, as one EMP expert stated in recent testimony, there are misconceptions regarding the nature and impact of potential EMP attacks, which may have a negative effect on the ability of stakeholders to determine reasonable steps needed to protect critical infrastructure and mitigate potential impacts.[35] One industry association further noted that the lack of threat information regarding EMP attacks makes it more difficult for their members to justify to their management, shareholders, or regulators the need for investments in EMP protective measures.

Vulnerability and Consequence

DHS components have also conducted some research efforts to better understand the impacts to electrical infrastructure from EMP or GMD events; however, opportunities exist to leverage additional information through existing DHS programs and enhanced collaboration with federal partners. While the NPPD Office of Infrastructure Protection (IP) conducts various assessments to identify vulnerabilities, interdependencies, and potential cascading impacts across different sectors of the nation's critical infrastructure, these have generally not been utilized to obtain specific information about vulnerabilities or consequences related to EMP or GMD events. Examples include the following:

- **Infrastructure Survey Tool (IST).** Through this program, IP administers survey questions to asset owners across all critical infrastructure sectors about key dependencies on utilities, including the supply of electric power.[36] However, DHS officials did not identify any efforts to utilize this information to develop any specific consequence assessments associated with potential cascading impacts of a widespread power grid failure, which could be caused by an electromagnetic event. According to DHS, over 300 IST's have been conducted at electrical substations since 2009 but, as of November 2015, the survey does not include any questions to capture

[35]Dr. George Baker, testimony before the House Committee on National Security and the House Subcommittee on the Interior, House Committee on Oversight and Government Reform (May 13, 2015).

[36]The IST is a voluntary, web-based vulnerability survey conducted by DHS Protective Security Advisors to identify and document the overall security and resilience of private-sector facilities and recommend measures to mitigate those vulnerabilities. These surveys, in conjunction with other visits by IP, indicated that of the 3,352 infrastructure assessments conducted through June 2014, 90 percent of those operations were dependent on electrical power.

the extent to which any specific protective equipment or mitigation measures may have been employed to address electromagnetic vulnerabilities.[37]

- **Regional Resiliency Assessment Program (RRAP).**[38] DHS identified three RRAP projects—of the 56 conducted since 2009—in which an EMP or GMD risk was considered, among other risk events. DHS used summary information it obtained from these assessments (and other IP site visits) to inform products such as the June 2014 Sector Resiliency Report: Electric Power Delivery. However, NPPD did not identify any efforts to utilize RRAP findings to develop more rigorous vulnerability or consequence analyses. For example, RRAP findings could help inform more detailed modeling of sector interdependencies, as called for by the EMP Commission, or serve as input to the identification of critical electrical infrastructure assets that could be impacted by electromagnetic events. Further, our review of a resiliency assessment from one of the three applicable RRAP projects indicated that although an EMP or solar storm was used as one of several threat scenarios that could disrupt the infrastructure assets of focus, there was limited discussion about specific asset vulnerabilities to such an event or identification of any additional information needed to inform future analysis.

- **Defense Critical Infrastructure Program.** This DOD program is conducted to assess infrastructure and other key military assets in the United States using a range of threat scenarios including EMP events. Among other functions, these assessments identify critical assets and identify vulnerabilities, including dependence on the commercial electric grid. Such information could assist DHS in efforts to identify critical substations supporting DOD facilities and further inform risk-assessment activities. Although DOD officials indicated some

[37]The IST is not designed to assess vulnerabilities to any specific hazards, however, the survey collects information regarding protective and mitigation actions taken that could include shielding or hardening of control systems and other key assets against electromagnetic impacts, among other potential actions.

[38]An RRAP is a cooperative assessment of specific critical infrastructure within a designated geographical area and a regional analysis of the surrounding infrastructure led by the NPPD Office of Infrastructure Protection. The RRAP addresses a range of hazards that could have regionally and nationally significant consequences. Each year, DHS selects these voluntary, nonregulatory RRAP projects with input and guidance from federal and state partners.

collaboration with DHS Protective Security Advisors when RRAP projects are conducted in areas with applicable defense assets or installations, they reported that DHS and DOD had not coordinated to review the results of DOD's assessments under the Defense Critical Infrastructure Program.

Collecting and utilizing risk information obtained through the above programs could help DHS to better understand the specific consequences across different sectors that may result from long-term electrical power outages, and may contribute to efforts to identify critical electrical infrastructure and asset protection priorities. For example, further collection of information on sector interdependencies could help DHS to assess the potential economic consequences associated with long-term power outages. Assessment of direct and indirect economic consequences is currently limited but could be useful to help determine relative risk rankings and provide information to help assess the cost-effectiveness of various mitigation strategies.

Further, a more comprehensive assessment of vulnerability and consequences may help inform broader DHS risk assessment efforts, including the HSNRC. These vulnerability and consequence inputs are key components to help ensure that the HSNRC can be effectively utilized to identify the relative rankings of various risk events, including other threats to the electrical grid, such as physical or cyberattack. According to officials within the DHS Office of Policy, the original HSNRC process conducted in 2012-2013 included estimates of broad consequences for 40 individual risk events. However, officials noted that certain categories, such as loss of life, were primary factors in designating selected risk events as priorities for further analysis.[39] These officials also reported that given limited information about the specific consequences likely to result from an EMP event, DHS instead utilized proxy consequence information from an analytical study of a major regional earthquake that would be expected to cause damage to a wide range of critical infrastructure including electrical power operations.[40] However, this

[39]In moving forward with the 2015 HSNRC, DHS policy officials stated that they planned to use more comprehensive and comparable quantitative data sources, such as total number of reported injuries, illnesses, and economic data, as well as cases of psychological impact and social displacement.

[40]Amr S. Elnashai et al., *Impact of New Madrid Seismic Zone Earthquakes on the Central USA vol. 1*, MAE Center Report No. 09-03 (Urbana, Ill.: Mid-America Earthquake Center, 2009).

postulated event—which included an estimate of approximately 86,000 injuries and fatalities across the 8-state study region—is unlikely to be on par with an EMP attack that, according to experts, could include the extended disruption of electric power and cascading impacts to other critical infrastructure across much of the United States.

According to the NIPP, to assess risk effectively, critical infrastructure partners—including owners and operators, sector councils, and government agencies—need timely, reliable, and actionable information regarding threats, vulnerabilities, and consequences. Under the NIPP, DHS's responsibilities include establishing and maintaining a comprehensive, multitiered, and dynamic information-sharing network designed to provide timely and actionable threat information, assessments, and warnings to public- and private-sector partners. In addition, the Quadrennial Energy Review specifically notes the importance of applicable threat information, stating that incomplete or ambiguous threat information may lead to inconsistency in physical security among grid owners, inefficient spending of limited resources at facilities, or deployment of security measures against the wrong threat.[41] The Quadrennial Energy Review also states that, in regard to critical high-voltage transformers, current programs to address vulnerability may not be adequate to address the security and reliability concerns associated with simultaneous failures of multiple high-voltage transformers.

Moreover, according to subject-matter experts, the impact to the electric grid from electromagnetic threats may vary substantially by location, network and operating characteristics, and other factors. For example, key reports on GMD indicate that high-voltage transformers located at higher latitudes in the United States are likely subject to increased potential for adverse impacts from GMD events than those at lower latitudes.[42] However, this is not the case with EMP, which may have impacts equal to or greater than GMD in any latitude of the United States. Additionally, an EMP would subject infrastructure assets to a combination of E1, E2, and E3 effects compared to GMD which only produces impacts

[41]The White House, *Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure* (Washington, D.C.: April 2015).

[42]See, for example, North American Electric Reliability Corporation, *2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbances on the Bulk Power System* (Atlanta, Ga.: February 2012).

similar to the E3 effect. Federal and industry researchers have also noted that given these distinct effects and the different types of mitigation efforts necessary to protect against them, more comprehensive risk information may be necessary to evaluate their unique impacts to the electric grid. The electric grid remains vulnerable to other potential threats, such as physical and cyberattacks, which each present unique vulnerabilities to assess. Better collection of threat, vulnerability, and consequence information through existing DHS programs and strengthened collaboration with federal partners could help DHS better assess the relative risk ranking of electromagnetic events versus other risks and help determine potential protection priorities to address identified vulnerabilities.

Federal Agencies Have Not Fully Coordinated Efforts to Implement Key EMP Risk Management Activities

Key federal agencies, including DHS and DOE, as well as industry partners have not established a fully coordinated approach to identifying and implementing risk management activities to address EMP risks. According to the NIPP Risk Management Framework, such activities include identifying and prioritizing research and development efforts, and evaluating potential mitigation options, including the cost-effectiveness of specific protective equipment. The publication of the National Space Weather Action Plan in October 2015 identified many key federal activities in these areas regarding the GMD risk; however, no similar efforts have been proposed regarding EMP risks to the electric grid.[43]

EMP Research and Development

There are several areas of EMP research highlighted in previous studies where coordinated federal involvement could help address identified gaps and further inform risk assessment efforts. For example, a recent effort funded by DOE—and conducted by Idaho National Laboratory (INL)—identified the need for updated research and analysis regarding the likely impacts of the E1, or early time pulse, of an EMP event. According to the report, most information sources on the impact of EMP E1 to electric power grids are decades old, include only observational information, and do not account for modern grid technologies and electronic control systems. For example, the report states that assessing the effectiveness

[43]Among other actions, the *National Space Weather Action Plan* lays out responsibilities for federal entities to establish benchmarks for space weather events, which are intended to serve as inputs into such activities as developing vulnerability assessments, creating engineering standards, and developing more effective mitigation practices and procedures.

of routinely recognized protective actions such as shielding equipment in faraday cages remains difficult given the limited experimentation data available, outside of DOD.[44] As a result, the report notes that the electric power industry may not have sufficient information regarding EMP effects to design adequate protections. Overall, the report concludes that there are more unknowns than knowns regarding EMP effects and mitigation, and recommends that the government collect additional data on E1 threats, their impact to the electric grid, and potential mitigation measures.

A 2013 white paper developed by a leading research organization for the electric industry also reported a lack of widespread and coordinated research and development efforts to protect and mitigate effects of EMP attacks against the commercial electric grid.[45] Among the specific actions identified is a recommendation for stakeholders to define key characteristics of an EMP event—such as potential altitudes of detonation—for further study of corresponding impacts. According to this paper, and representatives from an individual utility we interviewed, the lack of more specific parameters for determining potential EMP effects makes it difficult to develop applicable protective guidelines and equipment design specifications.[46] However, FERC officials noted that additional work is being done outside of the United States to further develop applicable standards and implement equipment designed to mitigate the effects of or protect against EMP risks.

Further research and development efforts on EMP effects could also include evaluation of the impacts of additional devices intended to disrupt or destroy electrical infrastructure or control systems, such as intentional electromagnetic interference. Updated information on the specific electromagnetic effects of EMP events or intentional electromagnetic interference weapons could help ensure that protective and mitigation efforts are designed to be effective for multiple threat scenarios.

[44]A faraday cage is a generally metallic enclosure that completely surrounds an electronic system to provide a protective barrier from electromagnetic signals.

[45]Electric Power Research Institute, *Electromagnetic Pulse (EMP) and the Power Grid* (Palo Alto, Calif.: 2013).

[46]Within DOD, MIL-STD-188-125 serves as the principal standard for protecting critical military assets against EMP effects, along with a classified version of this standard.

Similarly, any proposed mitigation strategies resulting from efforts to address GMD, including the National Space Weather Action Plan, could also consider how effective these strategies might be against a potential EMP attack so that fully informed investment decisions can be made. For example, as one EMP expert noted in recent congressional testimony, if designing protective equipment to withstand specified levels of E3 effects from an EMP attack, there may be collateral benefits for providing protection against GMD effects; however, the reverse may not be true.[47] That is, protecting against identified benchmark levels of GMD may not prove sufficient to protect against EMP E3 impacts.

Evaluation of Protective Equipment

Another potential area for additional federal collaboration involves further research and evaluation of protective equipment intended to help mitigate the impacts of an EMP event. Such research, also identified in the 2008 EMP Commission report, may include further evaluation of EMP hardening or shielding strategies, as well as specific testing of commercial products intended to protect or mitigate the effects of EMP attacks on key infrastructure assets, such as transformers. Government and industry stakeholders cite potential adverse operational impacts that may result from the use of such devices as a reason for not retrofitting existing assets. According to one major electrical industry association, EMP impacts on the electric grid are not fully understood and many EMP mitigation techniques involve significant investment and remain unproven. Further evaluation of the effectiveness of these types of products may help to inform government and industry cost-benefit analyses and provide more sound estimates on the potential costs associated with implementation of various protective measures across the electric grid.[48] A lead researcher within DOE stressed that sound science is required to help inform any federal efforts to establish standards and protective guidelines intended to address the potential impacts of EMP. DOE

[47]Dr. George Baker, testimony before the House Committee on National Security and the House Subcommittee on the Interior, House Committee on Oversight and Government Reform.

[48]Few U.S. utilities have implemented EMP/GMD protective technologies to date, so limited data are available to provide sound cost estimates for widespread implementation of this type of equipment. However, one initial estimate regarding the cost of installation of a device intended to protect a single high-voltage transformer from potential GMD effects is approximately $250,000 for the equipment, with additional installation and engineering costs of approximately $200,000. According to a key research organization for the electrical industry, incorporating EMP or GMD protection into new designs or buildings is generally more cost-effective than retrofitting existing infrastructure.

officials further stated that assessing the cost-effectiveness of select EMP or GMD protective measures could also help state public utility commissions determine whether the cost of such measures can be included in base utility rates.

In addition to bringing additional information and expertise to the table, enhanced engagement by key federal agencies could present opportunities for stakeholders to jointly fund and develop collaborative research projects. Among a few potential examples identified by government and industry stakeholders would be additional research and testing conducted at DOE National Laboratories or even possible pilot projects performed at government-operated utilities.[49]

The NIPP calls for the implementation of risk-management activities, which includes research and development to reduce vulnerabilities that have proven difficult or expensive to address. Additionally, the Energy Sector-Specific Plan states that energy-sector partners such as DHS and DOE are to pursue a focused, coordinated management approach that aligns current activities to research and development goals and milestones, initiates specific projects to address critical gaps, and provides a mechanism for collaboration, project management, and oversight. This approach aims to develop clearly defined activities, projects, and initiatives with time-based deliverables that are tied to priority research and development requirements. Given the limited experimental data regarding EMP effects on the electric grid, additional collaboration among government agencies and industry regarding EMP-related research and development could help fill existing information gaps and help better understand EMP effects on the electrical grid.

DHS officials and industry representatives noted that some discussion of EMP, including areas for additional research, has been conducted within forums such as the Electricity Subsector Coordinating Council, but that it has not surfaced as a key priority.[50] In addition, DHS officials stated that

[49]Bonneville Power Administration and Tennessee Valley Authority are federal agencies who self-fund their operations from the sale of electricity.

[50]The Electricity Subsector Coordinating Council serves as the principal liaison between the federal government and representatives from the electric power industry, with the mission of coordinating efforts to prepare for, and respond to, national-level disasters or threats to critical infrastructure. The Council includes utility chief executive officers and trade association leaders representing all segments of the electric power industry. The Council is to meet at least twice annually.

an EMP attack generally remains a lower risk priority compared to other risk events with higher probability such as natural disasters or cyberattacks. However, as discussed previously, it is not clear that DHS has assessed all available risk inputs regarding EMP events to develop fully informed relative risk rankings. Officials also noted that efforts to comply with Office of Management and Budget Circular A-11—which calls for executive-branch departments to adopt an enterprise risk-management approach—contributes to decisions regarding which operational risks to address given limited resources. Officials stated that, as a result, operational risks, such as counterterrorism and counterdrug efforts, remain higher priorities for the department than EMP and solar weather events, because these events represent a better opportunity for DHS to maximize its return on investment. DOE officials also noted resource limitations and competing priorities as the key driver for not pursuing additional risk management activities specifically related to EMP events.[51] However, DOE officials concurred that there is potential for enhanced collaboration with other federal agencies and industry stakeholders regarding identification of future research needs and priorities related to EMP.

Even if an EMP attack is not determined to be among the highest resource priorities for DHS and DOE relative to other risk events, there are opportunities for enhanced collaboration among federal agencies and industry stakeholders to address identified gaps and help ensure that limited resources are more effectively coordinated and prioritized. Better identification and implementation of key risk-management activities, including collaborative identification and support of research and development priorities, may help close some of the gaps identified regarding EMP events and provide the groundwork necessary for a more robust research-based evaluation of additional protection and mitigation options.

Conclusions

Given the foundational importance of electrical power to support other critical infrastructure sectors such as communications and transportation, not securing the electric grid from electromagnetic events could result in the loss of electrical services essential to maintaining our national

[51]According to DOE, a sophisticated and coordinated cyberattack, a catastrophic earthquake, and an extreme space weather event that causes widespread blackouts represent the three highest risks to the bulk-power system.

economy and security. Recognizing this possibility, federal agencies have taken a range of actions since 2008—when the EMP Commission report was issued—to provide guidance, conduct research, develop strategies and plans, and participate in training, among other things, to address electromagnetic risks to the electric grid. Although DHS's and DOE's actions were not taken directly in response to the EMP Commission's recommendations, they do align with their respective critical infrastructure protection responsibilities in law and policy, including under the NIPP. However, DHS could take additional actions to help address risks to the electric grid. Designating roles and responsibilities within DHS regarding electromagnetic risks could help ensure enhanced awareness of related activities within the department and improve coordination with other federal agencies and industry stakeholders. Once clear roles and responsibilities are established and communicated, DHS and other federal agencies will be better positioned to leverage their respective expertise to inform future actions.

One area in particular, where this collective expertise could be more fully leveraged is in determining the nation's critical electric infrastructure assets. Although FERC conducted a related analysis, it was completed without collaboration and input from DHS and DOE entities, and as a result opportunities may have been missed to leverage their unique knowledge and expertise. Additional collaboration to review FERC's analysis and determine whether further assessment is needed could help ensure that all applicable elements of criticality are being considered. While DHS recognizes that both space weather and power grid failure are risk events that can affect the nation's security, there are additional opportunities for DHS to collect key risk inputs, such as further collaboration with DOD to obtain applicable EMP threat, vulnerability, and consequence information. Additional data collection could also inform DHS's broader risk-assessment efforts to better determine the relative risk ranking of electromagnetic threats compared to other potential risks—a key factor in ensuring that protection and resource allocation priorities are appropriately considered and resourced.

Lastly, given the potentially significant impacts that an EMP attack would have on the electric grid and the potential cost of additional protective measures to mitigate against electromagnetic impacts, federal entities could better coordinate to identify and implement key EMP risk management activities. Such activities, including collaborative identification and support of research and development priorities, may help close some of the gaps identified regarding EMP events and provide

the groundwork necessary for a more robust research-based evaluation of additional protective efforts.

Recommendations for Executive Action

To enhance accountability for key risk-management activities and facilitate coordination with federal and industry stakeholders regarding electromagnetic risks, we recommend that the Secretary of Homeland Security designate roles and responsibilities within the department for addressing electromagnetic risks and communicate these to federal and industry partners.

To more fully leverage critical infrastructure expertise and address responsibilities to identify critical electrical infrastructure assets as called for in the NIPP, we recommend that the Secretary of Homeland Security and the Secretary of Energy direct responsible officials to review FERC's electrical infrastructure analysis and collaborate to determine whether further assessment is needed to adequately identify critical electric infrastructure assets, potentially to include additional elements of criticality that might be considered.

To enhance federal efforts to assess electromagnetic risks and help determine protection priorities, we also recommend that the Secretary of Homeland Security direct the Under Secretary for NPPD and the Assistant Secretary for the IP to work with other federal and industry partners to collect and analyze key inputs on threat, vulnerability, and consequence related to electromagnetic risks—potentially to include collecting additional information from DOD sources and leveraging existing assessment programs such as the IST, RRAP, and DCIP.

To facilitate federal and industry efforts to coordinate risk-management activities to address an EMP attack, we recommend that the Secretary of Homeland Security and the Secretary of Energy direct responsible officials to engage with federal partners and industry stakeholders to identify and implement key EMP research and development priorities, including opportunities for further testing and evaluation of potential EMP protection and mitigation options.

Agency Comments and Our Evaluation

We provided a draft of this report to DHS, DOE, DOD, NOAA, and FERC for their review and comment. DHS and DOE provided written comments, which are reproduced in appendices IV and V. In their comments, DHS and DOE concurred with each of the recommendations made to their respective departments and described actions underway or planned to

address them, including applicable timeframes for completion. If fully implemented, these actions should address the intent of the recommendations and better position DHS and DOE to further support federal and industry efforts to help protect the U.S. electric grid from electromagnetic events.

For example, in regards to designating applicable roles and responsibilities within the department, DHS noted that the Cyber, Infrastructure, and Resilience Policy Office within the DHS Office of Policy is currently developing its portfolio to further support electromagnetic risks. Specific actions identified to be completed by December 2016 include coordination across the department to identify and document applicable roles and responsibilities regarding electromagnetic issues to ensure full mission coverage while minimizing potential overlap or redundancy. In regards to engagement with industry stakeholders to identify and implement key research and development priorities, DHS and DOE each identified actions to convene applicable stakeholders to jointly determine mitigation options and conduct further testing and evaluation. DOE also identified that the department is working with EPRI to develop an EMP Strategy that lays out applicable goals and objectives. According to DOE, the EMP Strategy is scheduled for completion by August 31, 2016, and is to be followed by a more detailed action plan identifying R&D priorities and specific opportunities to test and evaluate EMP mitigation and protection measures.

DHS, DOE, NOAA, and FERC also provided technical comments, which we incorporated as appropriate. DOD did not provide comments on this report.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the Secretaries of Commerce, Defense, Energy, and Homeland Security, and the Chairman of the Federal Energy Regulatory Commission. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have any questions about this report, please contact me at (404) 679-1875 or curriec@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix IV.

Chris Currie
Director, Homeland Security and Justice

List of Requesters

The Honorable Ron Johnson
Chairman
Committee on Homeland Security and Governmental Affairs
United States Senate

The Honorable Pat Toomey
United States Senate

The Honorable Michael McCaul
Chairman
Committee on Homeland Security
House of Representatives

The Honorable Scott Perry
Chairman
Subcommittee on Oversight and Management Efficiency
Committee on Homeland Security
House of Representatives

The Honorable Patrick Meehan
House of Representatives

Appendix I: Overview of Geomagnetic Disturbance and Historical Events

According to research reports developed by subject-matter experts that we reviewed, geomagnetic disturbances (GMD) occur when the sun ejects charged particles that interact with and cause changes in the earth's magnetic fields. These charged particles typically reach the earth within 18 to 96 hours and can cause currents to enter the power system through long conductors, such as transmission lines. These currents can disrupt the normal operation of the power system and, in some cases, damage equipment such as transformers. Specific characteristics of the U.S. electric grid also make it potentially more vulnerable to GMD impacts. For example, the grid is located in northern latitudes, which is closer to the aurora of a geomagnetic storm, and near oceans which are filled with conductive salt water.

The Space Weather Prediction Center operated by the National Oceanic and Atmospheric Administration (NOAA) conducts continuous monitoring of solar activity and provides applicable watches, warnings, and alerts to stakeholders, including the electric power industry. If staff forecast that a coronal mass ejection is earth-bound, NOAA issues a watch that provides a 1 to 4 day notice that a geomagnetic storm is expected. Once the Deep Space Climate Observatory (DSCOVR) satellite—located 1 million miles from the earth—measures and provides data about the characteristics of the storm, forecasters can provide alerts between 15 to 60 minutes in advance of the storm hitting the Earth. These alerts may also include an index figure that describes the strength of the impending storm according to specific thresholds. Since 1859, scientists have observed GMD impacts on the earth. The following table describes notable GMD events and their respective impacts on electrical grid assets.

Table 3: Major Geomagnetic Disturbance (GMD) Events and Key Impacts

Year	Storm name	Magnitude	Impact
1859	Carrington Event	One-in-100-year storm Approx. 5,000 nT/min[a]	Telegraph wires shorted out in the United States and Europe, causing numerous fires
1921	New York Railroad Superstorm	One-in-100-year storm Approx. 5,000 nT/min	Telegraph fires in Sweden, damage to signal and switching system at New York Central Railroad.
1972	Space Age Solar Superstorm	One-in-30-year storm Approx. 2,200 nT/min	Knocked out long-distance telephone communication across Illinois. Caused AT&T to redesign its power system for transatlantic cables.
1989	March 1989 Superstorm	Approx. 900 nT/min[b]	Resulted in a shutdown of the Quebec power grid; six million people without power for 9 hours.

Year	Storm name	Magnitude	Impact
2003	Halloween Solar Storms	Approx. 480 nT/min	Caused a blackout of short duration in Southern Sweden and the loss of 15 extra-high-voltage transformers in South Africa.
2012	Solar Superstorm of July 2012	Comparable to Carrington Event	Hit but did not seriously damage STEREO-A satellite; missed the earth.

Source: GAO analysis of government and industry data. | GAO-16-243

[a]One of the most meaningful measures of the severity of impulsive geomagnetic field disturbances is the magnitude of the geomagnetic field change per minute, measured in nanoteslas per minute (nT/min).

[b]480 nT/min is the peak magnitude that caused the Hydro-Quebec power grid collapse. The March 1989 storm reached a peak magnitude of 869 nT/min over North America.

Appendix II: Summary of Key Federal Agency Actions Addressing Electromagnetic Risks to the Electric Grid

Standards, Guidelines, Tools, and Demonstration Projects

Since 2008, the Department of Homeland Security (DHS), the Department of Energy (DOE), and the Federal Energy Regulatory Commission (FERC) have taken an array of actions aimed at addressing electromagnetic risks to the electric grid. Because federal agencies do not own electrical grid infrastructure, their actions to address geomagnetic disturbance (GMD) threats are more indirect through such things as developing standards and guidelines and utilizing tools and demonstration projects. Specifically, federal agencies have taken steps to develop standards and guidelines. For example, the North American Electric Reliability Corporation (NERC) has begun the process of developing GMD reliability standards for FERC to review, and DHS has developed electromagnetic pulse (EMP) protection guidelines to safeguard critical assets and facilities. Below is a summary of these efforts and other actions taken by DHS, DOE, and FERC since 2013. Collectively, these actions are intended to protect critical infrastructure from both EMP and GMD events.

- **GMD Reliability Standards Rulemaking Process.** In May 2013, FERC directed a two-phase approach for NERC to develop reliability standards that address the impact of GMD on reliable operation of the bulk-power system. For the first phase, NERC developed and FERC approved a reliability standard that requires responsible entities to develop and implement operational procedures to mitigate the effects of GMD on the bulk-power system. The second phase, which is ongoing, is intended to provide more comprehensive protections by requiring responsible entities to protect their facilities against a benchmark GMD event. On January 21, 2015, NERC submitted to FERC a proposed second stage reliability standard that included a definition of a benchmark GMD event against which industry would have to assess and mitigate vulnerabilities. On May 14, 2015, FERC issued a Notice of Proposed Rulemaking seeking comments on NERC's proposal to approve, as well as its proposed modifications to the reliability standard, and other issues.[1] Public comments on the Notice were due near the end of July 2015, and FERC extended the comment date two additional times in response to developments in the record.[2] As of January 2016, FERC had not issued a final rule.

[1]80 Fed. Reg. 29,990 (May 26, 2015).

[2]According to DOE officials, one factor contributing to the extensions was the release of a DOE-funded analysis by the Los Alamos National Laboratory on the proposed standard.

- **EMP Protection Guidelines.** In November 2014, DHS developed guidelines to help federal agencies and industry identify options to protect critical equipment, facilities, and communication and data centers from various forms of EMP attacks, including High-Altitude EMP (HEMP), ground burst Source Region EMP, solar geomagnetic disturbances, and other Intentional Electromagnetic Interference, such as from radio frequency weapons. These guidelines include four levels of protection that are based on using specific devices, such as EMP-capable surge arresters on power cords to mitigate EMP vulnerabilities.

- **Solar Storm Mitigation.** In 2014, DHS led an effort to develop a forecasting tool that will enable more localized and precise geomagnetic induced current (GIC) forecast levels. In coordination with the National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA), among others, DHS intends to provide utility owners and operators with timely and accurate GIC forecast information, allowing them to make key operational decisions, such as shutting down, reducing power, or rerouting power to minimize the impact of a GIC event. DHS expects to complete this joint effort in fiscal year 2016.

- **Installation of Magnetometers.** In 2014, DOE funded an initiative to gather additional data on GIC and magnetic fields to help scientists validate models and develop more accurate estimations and modeling. As of October 2015, DOE reported plans to add 12 magnetometers to supplement the existing 6 that United States Geological Survey (USGS) has deployed nationwide. Two of those 12 will be fully funded by industry while 10 will be funded through a cost-share program between DOE and industry. These magnetometers are intended to provide owners and operators with real-time data on the expected currents that may impact their transformers. DOE officials added that this is a less costly alternative to deploying more monitors on transformers to measure actual currents during a GMD.

- **Recovery Transformer (RecX).** In 2012, DHS Science & Technology (S&T), with support from DOE and electricity sector representatives as part of the sector specific plan, partnered with industry to develop three prototype single-phase, extra-high-voltage transformers that could significantly reduce the time to transport, install, and energize a transformer to reduce recovery time from power outages associated with transformer failures from several months to less than 1 week. S&T, along with industry partners, piloted the RecX prototype for 2.5 years. DHS reported that RecX proved to be successful in an

operational environment and could potentially reduce the impact of power outages.

- **Resilient Electric Grid (REG).** In 2007, S&T partnered with industry to develop a fault current limiting high temperature superconducting cable that allows power substations to interconnect and share power in an internet-like fashion enabling multiple paths for power to flow while mitigating the risk of cascading fault currents. The cable system enables re-architecting urban area distribution grids to allow power to be rerouted in emergencies and will facilitate rapid and resilient recovery for grid outages. A prototype cable will be deployed in the grid in New York for a pilot demonstration. S&T is also evaluating a commercial scale deployment of the technology in downtown Chicago.

Research Reports

Key federal agencies, specifically DHS and DOE, have developed research reports to better understand the potential impacts of electromagnetic threats. Since 2007, DHS and DOE have developed or commissioned 17 key research reports addressing both EMP and GMD events. Some of the DHS-commissioned reports, authored by external industry experts, focused primarily on analyzing the impacts of EMP threats, including HEMP and Source Region EMP, while others assessed the potential impact of GMD events, including solar superstorms. Specifically, one DHS-commissioned report identified three main approaches to lessen the impact of a severe geomagnetic storm.[3] That report concluded that thorough research, testing, and cost analysis will be required to determine the best approach. Three of DHS's additional research reports are highlighted below.

- **Electromagnetic Pulse Impacts on Extra High Voltage Power Transformers.**[4] This 2010 report analyzed the potential impact of an EMP on extra high voltage transformers—focusing primarily on transformer equipment designs and identifying specific mitigation efforts such as blocking devices that minimize the impact of GIC on the electric grid. The report concluded that the similarity of EMP

[3]W. Radasky and J. Kappenman, *The Threat of a 100-Year Geomagnetic Superstorm to the U.S. Power Infrastructure, 2008*, Federal Emergency Management Agency (Alexandria, Va: Metatech Corporation, Jan. 20, 2008).

[4]Department of Homeland Security, *Electromagnetic Pulse (EMP) Impacts on Extra High Voltage Power Transformers, Rev. 2*, April 2010.

effects, regardless of source, indicates that solar weather provide a useful basis for transformer impact analysis and that selective installation of blocking devices would minimize the impacts of GIC on transformers, among other findings.

- **Impacts of Severe Space Weather on the Electric Grid.**[5] This 2011 report assessed the impacts of space weather on the electric grid, seeking to understand how previous solar storms have affected some electric grids, and what cost-effective mitigation efforts are available to protect the electric grid, among other topics. Some of the key findings and recommendations include the need for a rigorous risk assessment to determine how plausible a worst-case scenario may be and additional research to better understand how transformers may be impacted by electromagnetic risks. This report also recommended the potential installation of blocking devices to minimize the impacts of GIC.

- **Sector Resilience Report: Electric Power Delivery.**[6] This 2014 report summarizes an analysis of key electric power dependencies and interdependencies, such as communications, transportation, and other lifeline infrastructure systems. The report included an assessment of, and best practices for, improving infrastructure resilience such as: modeling to identify potential vulnerabilities, conducting a cost-benefit analysis of alternative, technology-based options, and installing protective measures and hardening at-risk equipment, among others.

Federal agencies have also sponsored research studies and identified risk information regarding electromagnetic risks. Below is a summary of key studies identified that address possible EMP mitigation and protective measures, the procurement and supply environment of large power transformers, susceptibility of transformers to GMD events, and the potential impact of a GMD event.

- **Six Technical Reports Addressing EMP Impacts on the U.S. Power Grid.** In January 2010, the Oak Ridge National Laboratory

[5]MITRE, *Impacts of Severe Space Weather on the Electric Grid*, JSR-11-320 (McLean, VA: November 2011).

[6]Department of Homeland Security, *Sector Resilience Report: Electric Power Delivery* (June 11, 2014).

(ORNL) developed six technical reports—authored by external industry experts—for DOE, DHS, and FERC, that examined the EMP threats and their potential impacts, and analyzed potential solutions for preventing and mitigating their effects.[7] Some of the reports key findings and recommendations include efforts to develop, test, and deploy mitigation technologies to automatically protect the power grid from costly damage, and to improve reporting and monitoring of GMD and power grid events.

- **Idaho National Laboratory Study on EMP.** In November 2015, DOE's Idaho National Laboratory released a study to identify and describe possible EMP mitigation and protection measures, to examine the measures' cost effectiveness, and to provide some potential strategies and solutions to reduce the effects of EMP on the commercial bulk electric grid. The report also discusses protection strategies for the electric grid and identifies future actions to be taken by both government and industry to enhance the security of the energy infrastructure.

- **Large Power Transformer Study.** In April 2014, DOE updated its 2012 report on Large Power Transformers and the U.S. Electric Grid that assessed the procurement and supply environment of large power transformers. In this research report, DOE examined the characteristics and procurement of large power transformers, and the availability of global and domestic suppliers, and assessed the potential risks facing these transformers, among others. The DOE report also updates the prior 2012 study and discusses new government and industry efforts to augment risk management options for critical infrastructure, including power transformers.

- **Oak Ridge National Laboratory Study on the Susceptibility of Transformers to GMD.** In November 2015, DOE officials reported initiating a study by ORNL to quantify the risks associated with GMD on electric power system reliability. The study plans to identify power lines and their associated transformers within the eastern section of the power grid and to determine those that are most susceptible to the effects of GMD. DOE officials expect the study to be completed in July 2016.

[7]Oak Ridge National Laboratory, *Electromagnetic Pulse: Effects on the U.S. Power Grid* (January 2010).

- **Pacific Northwest National Laboratory Study on Geomagnetic Storms and Long-Term Impact on Power Systems.** In December 2011, DOE's Pacific Northwest National Laboratory conducted a study to determine the potential impact of a severe GIC event on the western U.S.-Canada power grid, referred to as the Western Interconnection.[8] The study results indicated that the Western Interconnection was not substantially at risk to GIC because of the relatively small number of transmission lines that did not include series capacitors. The report recommended that the electric power industry consider the adoption of new protective relaying approaches that will prevent GIC events from damaging transformers.

Strategy Development and Planning

Since 2008, key federal agencies have taken actions to develop strategic plans to address the impact of GMD events to the electric grid. Specifically, DHS and DOE have developed key planning efforts that identify specific goals and outline key activities addressing electromagnetic risks. Below is a summary of DHS's efforts.

- **National Space Weather Strategy and Action Plan.** In October 2015, the White House Office of Science and Technology Policy (OSTP), DHS, and NOAA, in collaboration with DOE and other key federal agencies, issued the National Space Weather Strategy and Action Plan. As a co-chair of the Space Weather Operations, Research and Mitigation Task Force, DHS was jointly responsible for developing a strategy to achieve several goals, including efforts to establish benchmarks for space weather events, enhance response and recovery capabilities, improve protection and mitigation efforts, and improve assessment, modeling, and prediction of impacts on critical infrastructure, among other goals. The strategy identifies goals and establishes the principles that will guide these efforts in both the near and long term, while the Action Plan identifies specific activities, outcomes, and timelines that the federal government will pursue accordingly.

- **Power Outage Incident Annex.** In 2014, FEMA, in coordination with DOE, began developing a Power Outage Incident Annex to provide incident-specific information in support of the National Response and

[8]Pacific Northwest National Laboratory, *Geomagnetic Storms and Long-Term Impacts on Power Systems,* PNNL-21033 (December 2011).

National Disaster Recovery Frameworks.[9] Although not specific to addressing electromagnetic events, such as EMP and solar weather, according to FEMA officials, the incident annex will describe the process and organizational constructs that the federal government will utilize to respond to and recover from loss of power resulting from deliberate acts of terrorism or natural disasters. Among other tasks, the incident annex is designed to identify key federal government capabilities and resources, prioritize core capabilities, and outline response and recovery resource requirements. FEMA officials reported that the incident annex is scheduled to be completed by mid-2016.

Below is a summary of DOE's strategy development and planning efforts.

- **National Transformer Strategy.** In 2015, DOE developed a draft national strategy to reduce the risk to grid reliability posed by the loss of critical large power transformers. As drafted, the National Strategy for Reducing Risk from the Loss of Large Power Transformer focuses on protecting the bulk electric system—a system of 9,000 electric generating units connected across over 200,000 miles of high-voltage transmission lines—and ensuring the nation's supply of electricity remains resilient. To achieve these efforts, the draft national strategy focuses on three areas: (1) understanding and mitigating current and future risks to transformers, (2) enhancing protection of transformers, and (3) ensuring transformer replacement equipment is available. The draft national strategy also calls upon federal government entities, to partner with electricity operators, equipment manufacturers, and state and local authorities to develop risk assessments and modeling tools to guide their efforts and prioritize activities. As of December 2015, DOE officials reported that the strategy is undergoing ongoing review.

- **Quadrennial Energy Review.** In April 2015, the White House Quadrennial Energy Review Task Force, with support from DOE and other federal agencies, issued its first installment of the Quadrennial Energy Review, which addresses infrastructure for energy

[9]The National Response Framework is a guide to how the nation responds to disasters and emergencies of all types and describes the principles, roles and responsibilities, and coordinating structures for delivering the core capabilities required to save lives, protect property and the environment, stabilize communities, and meet basic human needs following an incident.

transmission, storage, and distribution.[10] A key chapter of this report focuses on a broad range of challenges and how the electric grid is vulnerable, specifically transformers, to a range of potential risks, including solar storms and EMP events. The report acknowledges that the federal government can fill gaps in creating data sets, tools, and assessments that provide a more complete and robust analytical approach towards measuring resilience needs and investments. Furthermore, the report recommends that DOE, in collaboration with DHS and others, develop common analytical frameworks, tools, and data to assess the resilience of energy infrastructures and to mitigate the risks associated with the loss of transformers.

Training and Outreach

Key federal agencies, such as DHS, DOE, and FERC, have also developed training and outreach efforts that could help address the potential impact of power outages caused by electromagnetic threats, such as a GMD event. Specifically, since 2012, DHS has reported participating in several briefings before conferences and training workshops that addressed electromagnetic threats, including EMP and solar weather events. Several of the briefings summarized the findings identified by previously issued DHS-commissioned research reports. For example, DHS gave presentations on multiple occasions about the potential impacts of an EMP event, including likely impacts on regional communication systems within major U.S. cities. DHS officials reported that as a result of these briefings, DHS has subsequently developed EMP protection guidelines to help federal agencies identify options for safeguarding critical equipment, facilities, and communication centers. These guidelines include four levels of protection that are based on using specific devices, such as EMP-capable surge arresters on power cords to mitigate EMP vulnerabilities. Below is a summary of DHS's additional training and outreach efforts.

- **GridEx II.** In November 2013, DHS and DOE, along with the Federal Bureau of Investigation, and other relevant government agencies, participated in an industry-wide exercise assessing the readiness of the electric industry to respond to a physical or cyberattack on the bulk-power system. The key goals of GridEx II were to review existing command, control, and communication plans and tools, incorporate

[10]White House Quadrennial Energy Review Task Force, *Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure*, April 2015.

lessons learned from a previous exercise, and to identify potential improvements in cyber and physical security plans and programs. Upon completing the exercises, participants identified key lessons learned, which included the need for enhanced information sharing, and clarification of roles and responsibilities during a physical or cyberattack.

- **Secure Grid.** In October 2011, DHS, along with multiple federal agencies and industry representatives, participated in a 2-day security exercise to assess the federal government's response to an extreme solar weather event. The exercise entailed a crisis simulation with the goal of exploring how private and government agencies would respond to a solar storm causing widespread power outages and damage to the electric grid, how they might cooperate during such a crisis, and to explore what steps could be taken to mitigate such severe events. Two of the key findings, among others, cite the need to develop a national strategy to determine the costs of hardening the electric grid against space weather events, and the need to conduct a comprehensive study to assess the cascading effects of a widespread and long-term shutdown of the electric grid caused by a space weather event.

Below is a summary of DOE and FERC's training and outreach efforts.

- **Space Weather Workshops.** In 2015, DOE conducted multiple training workshops addressing space weather issues and its potential impact on the electric grid. For example, in February 2015, DOE cosponsored a North Atlantic Space Weather workshop with the White House and international representatives from the United Kingdom, the Republic of Ireland, and Canada. DOE officials reported that the primary focus on the workshop was discussing the potential impact of space weather on power grids. In March 2015, DOE also co-sponsored a workshop with its Canadian counterpart, Natural Resources Canada. Similarly, in April and June 2015, DOE participated in training workshops with the Idaho National Laboratory and Electric Power Research Institute and discussed the potential impact that space weather and EMP events may have on the electric grid.

- **GMD Technical Conference.** On April 30, 2012, FERC held a technical conference to discuss issues related to the reliability of the bulk-power system as affected by GMD events and to explore the risks and impacts from GIC to transformers and other equipment on the bulk-power system, as well as options for addressing or mitigating

the risks and impacts. Participants included members from federal agencies, industry stakeholders, and academia. Panelists agreed that a collective effort is needed to protect the electric grid and that a national standard would be beneficial to assure effective and consistent protection. FERC officials we interviewed familiar with the technical conference stated that many participants agreed that there could be a cascading series of effects of a GMD event and there is a need to address this risk to help prevent a grid collapse. On March 1, 2016, FERC convened a second technical conference on GMD to discuss issues related to the proposed Reliability Standard for Transmission System Planned Performance for Geomagnetic Disturbance Events.

Appendix III: Summary of Alignment between 2008 EMP Commission Recommendation and Key Federal Agency Actions

Table 4: Summary of 2008 EMP Commission Recommendations Addressing Electrical Infrastructure and Alignment with DHS and DOE's Actions Taken to Address Electromagnetic Threats

Electromagnetic Pulse (EMP) Commission recommendations[a]	Summary of Department of Homeland Security (DHS) and Department of Energy (DOE) actions taken to address electromagnetic risks[b]
1. The commission recommends research be conducted to better understand infrastructure system interdependencies and interactions, along with the effects of various EMP attack scenarios. In particular, the commission recommends that such research include a strong component of interdependency modeling. Funding could be directed through a number of avenues, including DHS and National Science Foundation.	**Some action**. Between 2007 and 2015, DHS and DOE developed or commissioned 17 key research reports that address electromagnetic threats. Below is a summary of selected DHS and DOE reports: • *EMP Impacts on Extra High Voltage Transformers* • *Impacts of Severe Space Weather on the Electric Grid* • *Sector Resilience Report: Electric Power Delivery* • *The Threat of a 100-Year Geomagnetic Superstorm to the U.S. Power Infrastructure* • *The Threat of Source Region Electromagnetic Pulse (SREMP) on the U.S. Infrastructure* • *An Assessment of the Threat Potential to the U.S. Electric Power Grids from Extreme Space Weather Storms—An Analysis of U.S. Power System Impacts from Large Power Geomagnetic Storm Events* • *Geomagnetic Storms and Their Impacts on the U.S. Power Grid* • *The Early Time (E1) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid* As of November 2015, DHS had developed one report that specifically focused on infrastructure system interdependencies and interactions, as called for in the commission recommendation. However, the information contained in this report does not fully address the commission recommendation, which calls for more complex interdependency modeling and simulation research.
2. The commission recognizes current interest in protecting SCADA systems from electronic cyber assault. The commission recommends that such activities be expanded to address the vulnerability of SCADA systems to other forms of electronic assault, such as EMP.	**Some action.** DHS's National Cybersecurity and Communications Integration Center has taken action to model and assess the potential risks to the communications and control elements, such as SCADA, of the electric grid. Specifically, in November 2014, DHS developed EMP Protection Guidelines to help federal agencies and industry identify options for safeguarding critical assets, including control elements, such as SCADA. However, as of November 2015, DHS reported that these guidelines have not been widely implemented by any federal agency. One of the six DOE-commissioned studies, issued in January 2010, also assessed how power substations and control centers, such as SCADA, could be vulnerable to a HEMP.

Electromagnetic Pulse (EMP) Commission recommendations[a]	Summary of Department of Homeland Security (DHS) and Department of Energy (DOE) actions taken to address electromagnetic risks[b]
3. It is vital that DHS, as early as practicable, make clear its authority and responsibility to respond to an EMP attack and delineate the responsibilities and functioning interfaces with all other governmental institutions with individual jurisdictions over the broad and diverse electric power system. This is necessary for private industry and individuals to act to carry out the necessary protections assigned to them and to sort out liability and funding responsibility.	**Some action.** While not specifically addressing EMP, the recently completed National Space Weather Strategy and Action Plan, issued by the White House Office of Science and Technology Policy, outlines selected federal efforts to address space weather threats. The Action Plan calls for federal agencies to establish benchmarks for space weather events and to improve protection and mitigation efforts, among other actions. In addition, the Federal Emergency Management Agency (FEMA), in partnership with DOE, is also developing a Power Outage Incident Annex plan. This plan is designed to outline DHS's role in responding to and recovering from a long-term power outage, which may be caused by an EMP or GMD event. Although we identified these efforts to be a positive step toward clarifying DHS responsibilities to respond to electromagnetic threats, the Space Weather Action Plan does not also address the scope of responsibilities needed to respond to an EMP attack and the Power Outage Incident Annex is not scheduled for completion until the first half of 2016.
4. DHS particularly needs to interact with the Federal Energy Regulatory Commission (FERC), the North American Electric Reliability Corporation (NERC), state regulatory bodies, other governmental institutions at all levels, and industry in defining liability and funding relative to private and government facilities, such as independent power plants, to contribute their capability in a time of national need, yet not interfere with market creation and operation to the maximum extent practical.	**None.**
5. DHS must establish the methods and systems that allow it to know, on a continuous basis, the state of the infrastructure, its topology, and key elements. Testing standards and measurable improvement metrics should be defined as early as possible and kept up to date.	**None.**
6. Working closely with industry and private institutions, DHS should provide for the necessary capability to control the system in order to minimize self-destruction in the event of an EMP attack and to recover as rapidly and effectively as possible.	**None.**
7. DHS and DOE must utilize industry and other governmental institutions to assure the most cost effective outcome occurs and that it does so more rapidly than otherwise possible. In many instances, these initiatives are extensions or expansions of existing procedures and systems such as those of NERC. Separate recommended initiatives are listed below.	**Some action—see descriptions below.**

Electromagnetic Pulse (EMP) Commission recommendations[a]	Summary of Department of Homeland Security (DHS) and Department of Energy (DOE) actions taken to address electromagnetic risks[b]
a. Understand system and network level vulnerabilities, including cascading effects	DHS and DOE commissioned research reports to better understand how networks and systems are vulnerable to EMP attacks. For example, in 2014, DHS summarized cascading effects an EMP event may pose on other key lifeline infrastructures, such as communications and transportation infrastructures. Similarly, a 2010 DOE-commissioned report assessed network level vulnerabilities and identified both general and specific protection methods to withstand electromagnetic threats, such as HEMP.
b. Evaluate and implement quick fixes	**None.**
c. Develop national and regional restoration plans	Since October 2014, FEMA and DOE have been developing a Power Outage Incident Annex plan, which is designed to provide incident-specific information regarding how the federal government plans to respond a long-term power outage resulting from deliberate acts of terrorism or natural disasters, such as an EMP or GMD event. However, as of November 2015, DHS officials reported that the Power Outage Incident Annex plan is to be issued in the first half of 2016.
d. Assure availability of replacement equipment	In March 2012, DHS led the design and development of a prototype transformer, Recovery Transformer (RecX) that was operational for 2.5 years. As of November 2015, DHS has not reported plans to further develop or expand installation of spare transformers to other locations.
e. Assure availability of critical communications channels	In October 2014, DHS began developing recommended guidelines to safeguard critical equipment, facilities, and communication and data centers from an EMP attack. The intended goal was to provide federal agencies and critical infrastructure owners and operators a range of options for protecting their assets. As of November 2015, DHS's EMP Protection Guidelines have not been widely implemented by any federal agency.
f. Expand and extend emergency power supplies	**None.**
g. Extend black start capability	**None.**
h. Prioritize and protect critical nodes	**None.**
i. Expand and assure intelligent islanding capability	**None.**
j. Assure protection of high-value generation assets	**None.**
k. Assure protection of high-value transmission assets	**None.**
l. Assure sufficient numbers of adequately trained recovery personnel	**None.**
m. Simulate, train, exercise, and test the recovery plan	In October 2011, DHS participated in a security exercise to determine how industry and the federal government would respond to widespread damages to the electric grid caused by an extreme solar weather event, called Secure Grid. Similarly, in November 2013, DHS and DOE, along with other government agencies, participated in an industry-wide exercise, GridEx II, assessing industry's ability to respond to a physical or cyberattack on the bulk power system.

Electromagnetic Pulse (EMP) Commission recommendations[a]	Summary of Department of Homeland Security (DHS) and Department of Energy (DOE) actions taken to address electromagnetic risks[b]
8. Develop and deploy system test standards and equipment	**None.**
9. Establish installation standards	**None.**

Source: EMP Commission, and GAO analysis of DHS and DOE actions. | GAO-16-243

[a]The EMP Commission recommendations cited above capture two key areas identified in the report: Infrastructure Commonalities and Electric Power which both have a nexus to electrical infrastructure. The Commission also made recommendations addressing potential EMP impacts affecting other infrastructure sectors, such as Telecommunications, Banking, and Emergency Services, among others.

[b]These actions were characterized as "some action" because not all elements of the EMP recommendation were fully addressed.

Appendix IV: Comments from the Department of Energy

Department of Energy
Washington, DC 20585

March 9, 2016

Mr. Christopher Currie
Director
Homeland Security and Justice
U.S. Government Accountability Office
Washington, D.C. 20548

Dear Director Currie:

The Department of Energy (DOE) appreciates the opportunity to respond to the Government Accountability Office's (GAO) Draft Report "Critical Infrastructure Protection – Federal Agencies Have Taken actions to Address Electromagnetic Risks, but Opportunities Exist to Further Assess Risks and Strengthen Collaboration."

DOE's response to the Report's draft recommendations that involves DOE is as follows:

Recommendation 1: "...the Secretary of Homeland Security and the Secretary of Energy direct responsible officials to review FERC's electrical infrastructure analysis and collaborate to determine if further assessment is needed to adequately identify critical electric infrastructure assets, potentially to include additional elements of criticality that might be considered."

Response: DOE concurs. The Office of Electricity Delivery and Energy Reliability will review FERC's electrical infrastructure analysis. Furthermore, DOE will work with FERC and DHS to identify any additional elements of criticality and determine if further assessment is needed, by March 31, 2017.

In a related effort, required by the FAST Act[1], FERC, after consultation with the Secretary of Energy shall promulgate such regulations as necessary to —

> "(A) establish criteria and procedures to designate information as critical electric infrastructure information;
>
> "(B) prohibit the unauthorized disclosure of critical electric infrastructure information.

[1] The FAST Act defines Critical Electric Infrastructure as "a system or asset of the bulk-power system, whether physical or virtual, the incapacity or destruction of which would negatively affect national security, economic security, public health or safety, or any combination of such matters."

Recommendation 2: **"...the Secretary of Homeland Security and the Secretary of Energy direct responsible officials to engage with industry stakeholders to identify and implement key EMP research and development priorities, including opportunities for further testing and evaluation of potential EMP protection and mitigation options."**

Response: DOE concurs. The Department of Energy and the Electric Power Research Institute are currently working on the development of a joint DOE/Electricity Industry EMP Strategy which lays out goals and objectives. The Strategy is expected to be complete by August 31, 2016. Detailed action plans to implement the goals from the Strategy will be developed by DOE and by industry within six months of approval of the Strategy by the Secretary. DOE's and Industry's actions will identify R&D priorities and identify specific opportunities and areas for further test and evaluation of EMP mitigation and protection measures. We expect there will be both Government-funded and Industry-funded R&D and testing and evaluation as part of the action plans. In development of the Strategy and Action plans, DOE will collaborate, not only with industry, with also with other Federal government partners (including the Departments of Homeland Security and the Department of Defense).

In a separate related activity, DOE will soon release an Idaho National Laboratory report that identifies potential measures utilities can take to mitigate and protect against the effects of EMP. The report points out knowledge gaps and recommends some areas for further R&D. These recommendations will be considered when developing the Action plans to implement the Joint DOE/Industry EMP Strategy.

Thank you, again, for the opportunity to provide comment on the draft report. We look forward to receiving your final report.

Sincerely,

Patricia A. Hoffman

Patricia A. Hoffman
Assistant Secretary
Office of Electricity Delivery and Energy Reliability
U.S. Department of Energy

Appendix V: Comments from the Department of Homeland Security

U.S. Department of Homeland Security
Washington, DC 20528

Homeland Security

March 4, 2016

Chris Currie
Director, Homeland Security and Justice
U.S. Government Accountability Office
441 G Street NW
Washington, DC 20548

Re: Draft Report GAO-16-243, "CRITICAL INFRASTRUCTURE PROTECTION: Federal Agencies Have Taken Actions to Address Electromagnetic Risks, but Opportunities Exist to Further Assess Risks and Strengthen Collaboration"

Dear Mr. Currie:

Thank you for the opportunity to review and comment on this draft report. The U.S. Department of Homeland Security (DHS) appreciates the U.S. Government Accountability Office's (GAO) work in planning and conducting its review and issuing this report.

The Department is pleased to note GAO's positive recognition that the actions recommended by the 2008 Electromagnetic Pulse (EMP) Commission Report generally align with existing DHS authorities and responsibilities related to critical infrastructure security and resilience. In terms of progress made in addressing electromagnetic risks, it is important to point out that DHS's Federal Emergency Management Agency (FEMA) and the Department of Energy (DOE) have jointly led the development of a power outage incident annex to the Response Federal Interagency Operational Plan, which describes how the federal government responds to and recovers from a loss of power resulting from deliberate acts of terrorism or natural disasters, including an EMP or geomagnetic disturbance (GMD) event. It is also important to note that DHS and DOE have led most of the federal actions addressing protection and mitigation efforts related to EMP and GMD events.

The draft report contained four recommendations with which the Department concurs. Specifically, GAO recommended that the Secretary of Homeland Security:

Recommendation 1: Designate roles and responsibilities within the department for addressing electromagnetic risks and communicate these to federal and industry partners.

Response: Concur. The Cyber, Infrastructure and Resilience (CIR) Policy Office within the DHS Office of Policy provides a critical integrating function across operational components that impacts the cybersecurity, infrastructure protection and resilience missions. CIR, while currently focusing on cyber issues, is developing its portfolio to support infrastructure and resilience issues, which will include electromagnetic (ELM) risk. To address this recommendation, CIR will coordinate across the Department to confirm which Components have ELM equities. CIR will also identify and document specific roles and responsibilities to ensure full mission coverage while minimizing overlap or redundancy as much as possible. In so doing, CIR will ensure a common understanding and articulation of relevant guidance vis-à-vis roles and responsibilities involving or affected by ELM. Estimated Completion Date (ECD): December 31, 2016.

Recommendation 2: Along with the Secretary of Energy, direct responsible officials to review FERC's [Federal Energy Regulatory Commission] electrical infrastructure analysis and collaborate to determine if further assessment is needed to adequately identify critical electric infrastructure assets, potentially to include additional elements of criticality that might be considered.

Response: Concur. The National Protection and Programs Directorate (NPPD) will collaborate with FERC to identify critical electrical infrastructure assets beginning with an evaluation of FERC identified critical substations. In addition, NPPD will explore additional elements of criticality that might not have been previously considered by FERC. This may include a more detailed analysis to assess black start power generating units.

To date, DHS and DOE have extensively reviewed the FERC electrical infrastructure analysis, and are working to refine the analysis and to expand our joint capabilities to assess operator contingency planning scenarios. This effort, which involves three of the national laboratories, will allow analysts to assess the impact and likelihood of extreme contingencies that may result in cascading events. Assessing the importance of critical electric infrastructure assets under numerous planning scenarios will allow DOE and DHS to prioritize such assets for a variety of purposes. ECD: March 31, 2017.

Recommendation 3: Direct the Under Secretary of NPPD and Assistant Secretary for the Office of Infrastructure Protection to work with other federal and industry partners to collect and analyze key inputs on threat, vulnerability, and consequence related to electromagnetic risks-potentially to include collecting additional intelligence information from DOD [Department of Defense] sources and leveraging existing assessment programs such as the IST [Infrastructure Survey Tool], RRAP [Regional Resiliency Assessment Program], and DCIP [Defense Critical Infrastructure Program].

Response: Concur. It is important to emphasize that the Department has already made efforts to assess electromagnetic risks and help determine protection priorities. At the

same time, NPPD continues to reinforce the importance of treating EMP with the same rigor that we treat other risks, and has integrated it into the Strategic National Risk Assessment, planning efforts, and other long term risk and vulnerability reduction efforts. Moving forward, NPPD will continue to encourage owners and operators of critical infrastructure and technology assets to coordinate development of realistic power-restoration priorities and expectations.

A joint DHS and DOE study is already underway regarding the impacts of EMP and GMD events on the electric grid. This study consists of four phases, which will analyze the hazard environments, impacts, and consequences of different sources of EMP and GMD on the U.S. electric power infrastructures, and to use those methods to determine EMP and GMD events of concern and potential means of mitigation. With respect to the potential of utilizing existing assessment tools, such as the IST and RRAP, it is important to note that there are significant limitations to the extent to which existing NPPD assessment programs, specifically the IST and RRAP can be leveraged to help implement this recommendation. The hazards and vulnerabilities addressed by RRAP projects are driven by the needs and requirements States and local owners and operators. If those customers do not require or desire EMP or GMD hazards to be examined, the RRAP will not include those elements.

With regard to the IST, it is by design a comparative survey of protective and resilience measures that does not include questions that pertain to any specific sector or questions about vulnerability to any specific hazard. In this regard, the IST methodology has limited applicability to the data collection and analysis activities in the context of this recommendation. Moreover, the IST is threat agnostic by design, and therefore enables state, local, and industry partners to apply the IST information to a range of scenarios, threats, and hazards to better characterize and improve their security decision making. Based on the reasons above, NPPD does not intend to pursue any modification of these assessment programs in response to this recommendation. However, DHS and its other Federal and industry partners will seek other, more readily applicable, assessment programs to collect and analyze electromagnetic risk information.
ECD: December 31, 2016.

Recommendation 4: Along with the Secretary of Energy, direct responsible officials to engage with industry stakeholders to identify and implement key EMP research and development priorities, including opportunities for further testing and evaluation of potential EMP protection and mitigation options.

Response: Concur. Key EMP research and development capability gaps and needs identified by joint government and industry stakeholders will be fed into DHS's Integrated Product Team (IPT) process for prioritization. This team is led by the DHS Science and Technology's (S&T) Homeland Security Advanced Research Projects Agency (HSARPA.) More specifically, HSARPA will work with DOE and the

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Electricity Subsector Coordinating Council to develop a joint government and industry approach to address the threat of EMP. Moving forward, in the short term, the partnership will convene government and industry stakeholders to identify available options for mitigating the consequences of an EMP event. In the long term, the goal will be to identify additional measures that can be developed, tested, and deployed to address specific EMP threats. ECD: September 30, 2016.

Again, thank you for the opportunity to review and comment on this draft report. Technical comments were previously provided under separate cover. Please feel free to contact me if you have any questions. We look forward to working with you in the future.

Sincerely,

Jim H. Crumpacker, CIA, CFE
Director
Departmental GAO-OIG Liaison Office

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Appendix VI: GAO Contact and Staff Acknowledgments

GAO Contact

Chris Currie, (404) 679-1875 or CurrieC@gao.gov.

Staff Acknowledgments

In addition to the individual named above, Dawn Hoff (Assistant Director) and Ryan Lambert (Analyst-in-charge) managed this assignment. Chuck Bausell, Kendall Childers, Katherine Davis, Josh Diosomito, Leah English, Tom Lombardi, John Rastler, and Steven Putansu made key contributions to this report.

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