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SUMMARY

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Space Weather: An Overview of Policy and Select U.S. Government Roles and Responsibilities

Space weather refers to conditions on the sun, in the solar wind, and within the extreme reaches of Earth's upper atmosphere. In certain circumstances, space weather may pose hazards to space-borne and ground-based critical infrastructure systems and assets that are vulnerable to geomagnetically induced current, electromagnetic interference, or radiation exposure. Hazardous space weather events are rare, but may affect broad areas of the globe. Effects may include physical damage to satellites or orbital degradation, accelerated corrosion of gas pipelines, disruption of radio communications, damage to undersea cable systems or interference with data transmission, permanent damage to large power transformers essential to electric grid operations, and radiation hazards to astronauts in orbit.

The National Aeronautics and Space Administration Authorization Act of 2010 (2010 NASA Authorization Act; P.L. 111-267) directed the White House Office of Science and Technology Policy (OSTP) to improve national preparedness for space weather events and to coordinate related federal space weather efforts. OSTP established the Space Weather Operations, Research, and Mitigation (SWORM) Working Group, which released several strategic and implementation plans, including the 2019 National Space Weather Strategy and Action Plan. The White House provided further policy guidance through two executive orders (E.O. 13744 and E.O. 13865) regarding space weather and electromagnetic pulses (EMPs), respectively.

The National Oceanic and Atmospheric Administration (NOAA) is the primary civilian agency responsible for space weather forecasting. Department of Energy national laboratories, the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF) support forecasting activities with scientific research. Likewise, the U.S. Geological Survey (USGS) provides data on Earth's variable magnetic field to inform understanding of the solar-terrestrial interface. The Department of Homeland Security disseminates warnings, forecasts, and long-term risk assessments to government and industry stakeholders as appropriate. The Department of Energy is responsible for coordinating recovery in case of damage or disruption to the electric grid. The Department of State is responsible for engagement with international partners to mitigate hazards of space weather. The Department of Defense (DOD) supports military operations with its own space weather forecasting capabilities, sharing expertise and data with other federal agencies as appropriate.

The 116th Congress enacted legislation that further defines agency missions and interagency relationships regarding space weather. The National Defense Authorization Act for Fiscal Year 2020 (FY2020 NDAA; P.L. 116-92) included a series of homeland security-related provisions that parallel the E.O. 13865 framework for critical infrastructure resilience and emergency response. The FY2020 NDAA also repealed a section of the National Defense Authorization Act for Fiscal Year 2018 (P.L. 115-91), which authorized a "Commission to Assess the Threat to the United States from Electromagnetic Pulse Attacks and Similar Events." In October 2020, Congress enacted the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act (PROSWIFT Act; P.L. 116-181), which directed multiple federal entities, including OSTP, NOAA, NASA, NSF, USGS, and parts of DOD, to improve space weather research, monitoring, forecasting, and preparedness in certain ways.

The Congressional Budget Office estimated that federal agencies participating in the SWORM Interagency Working Group "allocated a combined total of nearly $350 million to activities related to space weather" in FY2019. NASA allocated the majority ($264 million) of the $350 million total. The Consolidated Appropriations Act, 2022 (P.L. 117-103) continues support for maintenance and modernization of satellites used for space-weather forecasting. In addition, the Infrastructure Investment and Jobs Act (IIJA; P.L. 117-58) provides authorizations and appropriations that may support space weather resilience, among other purposes.

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Introduction

Space weather refers to the dynamic conditions in Earth's outer space environment. This includes conditions on the sun, in the solar wind, and in Earth's upper atmosphere.[1] Space weather phenomena include

- *solar flares* or periodic intense bursts of radiation from the sun caused by the sudden release of magnetic energy,
- *coronal mass ejections* composed of clouds of solar plasma and electromagnetic radiation, ejected into space from the sun,
- *high-speed solar wind streams* emitted from low density regions of the sun, and
- *solar energetic particles* or high-energy charged particles formed at the front of solar flares and coronal mass ejections.[2]

Hazardous space weather events are rare, but may cause geomagnetic disturbances (GMDs) that affect broad areas of the globe. Such events may pose hazards to space-borne and ground-based critical infrastructure (CI) systems and assets that are vulnerable to geomagnetically induced current, electromagnetic interference, or radiation exposure (see **Figure 1**).[3]

Several notable events illustrate how the impact of space weather hazards has broadened over time with technological advances. The 1859 "Carrington event," named for the British solar astronomer who first observed it, caused auroras as far south as Central America and disrupted telegraph communications. In 1972, a GMD knocked out long-distance telephone service in Illinois. In 1989, another GMD caused a nine-hour blackout in Quebec and melted some power transformers in New Jersey. In 2005, X-rays from a solar storm disrupted GPS signals for a short time.[4] In February 2022, at least 40 of 49 broadband internet satellites launched to low earth orbit by a Space Exploration Technologies (SpaceX) rocket were lost when a geomagnetic storm changed conditions in the upper atmosphere, causing orbital degeneration of the satellites.[5]

This report provides an overview of federal government policy developed under the existing legislative framework, and describes the specific roles and responsibilities of select federal departments and agencies responsible for the study and mitigation of space weather hazards. It includes information on legislation enacted in recent Congresses. Legislation in the 116th Congress further codified federal authorities, roles, and responsibilities in space weather research and forecasting. In the 117th Congress, the Consolidated Appropriations Act, 2022 (P.L. 117-103)

[1] National Aeronautics and Space Administration (NASA), "Space Weather," at https://www.nasa.gov/mission_pages/rbsp/science/rbsp-spaceweather.html.

[2] NASA, "Solar Storm and Space Weather—Frequently Asked Questions," at https://www.nasa.gov/mission_pages/sunearth/spaceweather/index.html#q2; National Science and Technology Council, *National Space Weather Strategy and Action Plan*, March 2019, at https://www.whitehouse.gov/wp-content/uploads/2019/03/National-Space-Weather-Strategy-and-Action-Plan-2019.pdf; and University of California at Berkeley, "Solar Flares and Coronal Mass Ejections," at http://cse.ssl.berkeley.edu/coronalweather/CMEsFlares/.

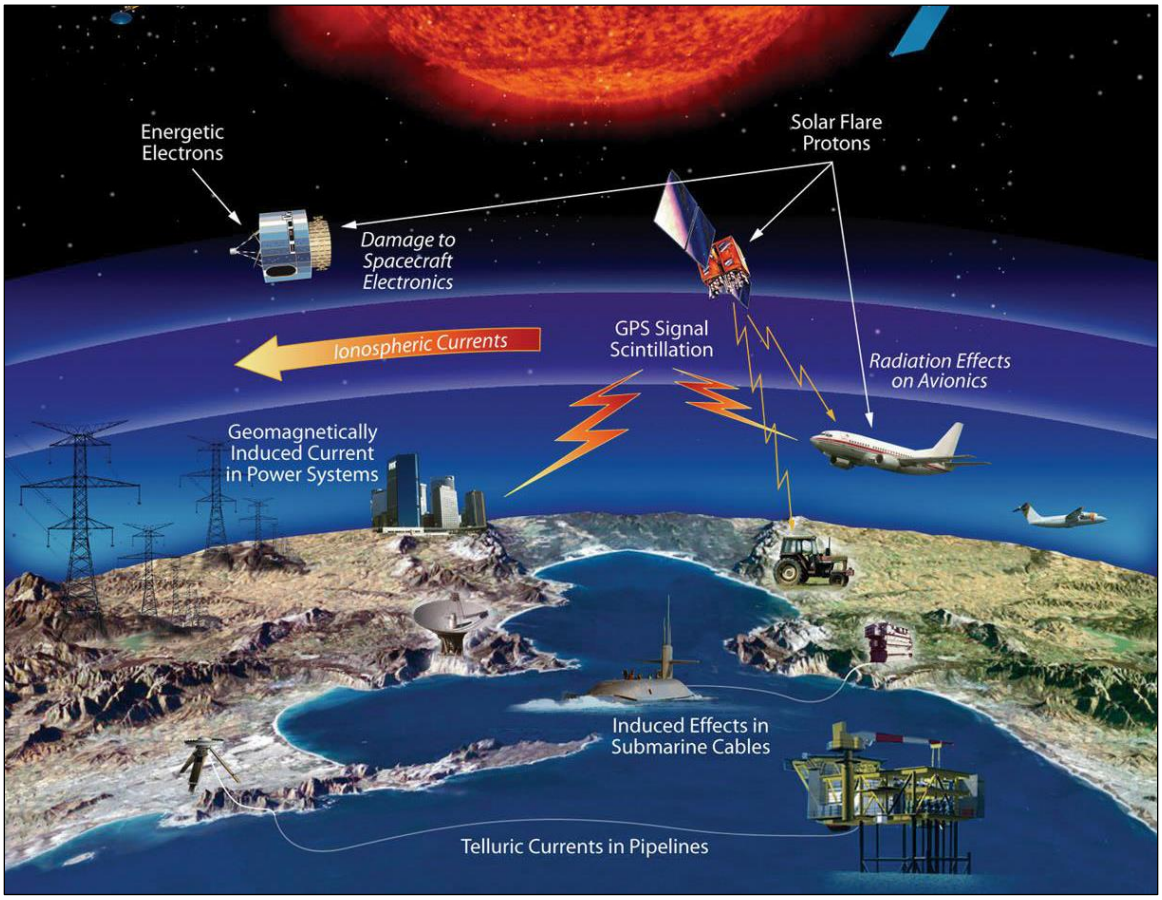
[3] Geomagnetic currents occur when changes in the Earth's magnetic field caused by space weather induce currents in power transmission lines or other long conductive lines. Such currents may cause damage to critical system components such as large power transformers. See Michael Kelly and Russell Bent, "GMD Coupling to Power Systems and Disturbance Mitigation," Los Alamos National Laboratory, January 24, 2018, online at https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-18-20499.

[4] See NASA, "A Super Solar Flare," at https://science.nasa.gov/science-news/science-at-nasa/2008/06may_carringtonflare.

[5] See SpaceX, "Updates: Geomagnetic Storm and Recently Deployed Starlink Satellites," https://www.spacex.com/updates/.

continues support for maintenance and modernization of satellites used for space-weather forecasting. In addition, the Infrastructure Investment and Jobs Act (IIJA; P.L. 117-58) provides authorizations and appropriations that may support space weather resilience, among other purposes.

Figure 1. Examples of Potential Effects of Space Weather



Source: NASA, email communication with NASA Office of Legislative and Intergovernmental Affairs, September 6, 2019.

Federal Interagency Activities and Major Legislation

Over the past several decades, the federal government's interest in space weather and its effects has grown. Congress has required individual federal agencies to conduct certain space weather-related activities related to agency missions. However, federal interagency work began in earnest with the establishment of the interagency National Space Weather Program (NSWP) in 1995 by the Department of Commerce's Office of the Federal Coordinator for Meteorology.[6] The NSWP Council included representatives from interested federal agencies. The NSWP Council

[6] Michael F. Bonadonna, "The National Space Weather Program: Two Decades of Interagency Partnership and Accomplishments," 2016, at https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2016SW001523. Hereinafter Bonadonna 2016.

coordinated federal space weather strategy development between 1995 and 2015 in partnership with federal agencies, industry, and the academic community.[7]

Space Weather Federal Coordination

In 2010, the Obama Administration released its "National Space Policy of the United States of America," which included a goal related to improving space-based Earth and solar observation capabilities to forecast terrestrial and near-Earth space weather and directed the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) to work on space weather forecasting, among other goals.[8] Under the 2010 NASA Authorization Act, Congress directed the White House Office of Science and Technology Policy (OSTP) to improve national preparedness for space weather events and to coordinate federal space weather activities of the NSWP Council.[9]

OSTP's National Science and Technology Council established the Space Weather Operations, Research, and Mitigation (SWORM) Working Group in 2014 to lead federal strategy and policy development.[10] The following year, SWORM published a national strategy for space weather preparedness, titled the "National Space Weather Strategy" (2015 Strategy), effectively deactivating the NSWP Council.[11] In 2016, President Obama signed Executive Order (E.O.) 13744, "Coordinating Efforts to Prepare the Nation for Space Weather Events," directing federal space weather preparedness activities to be carried out "in conjunction" with those activities already identified in the 2015 Strategy.[12]

The SWORM Interagency Working Group released an updated national space weather strategy in 2019, titled "The National Space Weather Strategy and Action Plan" (the 2019 Plan).[13] The same year, President Trump signed E.O. 13865, "Coordinating National Resilience to Electromagnetic Pulses," directing the federal government to "foster sustainable, efficient, and cost-effective approaches" to improve national resilience to the effects of electromagnetic pulses.[14]

[7] The NSWP Council was composed of representatives from the Departments of Defense, Energy, Homeland Security, the Interior, State, and Transportation; National Aeronautics and Space Administration (NASA); National Oceanic and Atmospheric Administration (NOAA); National Science Foundation (NSF); Office of Science and Technology (OSTP); and Office of Management and Budget (OMB). See Bonadonna 2016.

[8] Executive Office of the President, *National Space Policy of the United States of America*, June 28, 2010, pp. 4 and 12.

[9] P.L. 111-267; 42 U.S.C. §18388.

[10] SWORM is referred to as a working group or task force, depending on the document (see Bonadonna 2016 and National Science and Technology Council, *National Space Weather Strategy*, Washington, DC, October 2015). The SWORM Working Group is composed of representatives from the Federal Aviation Administration, Federal Bureau of Investigation, Federal Communications Commission, Federal Emergency Management Agency, Federal Energy Regulatory Commission, Federal Railroad Administration, NASA, NOAA, NSF, Nuclear Regulatory Commission, Office of the Director of National Intelligence, U.S. Air Force, U.S. Geological Survey, U.S. Navy, U.S. Postal Service, National Security Council, OMB, OSTP, and White House Military Office (SWORM, "About SWORM," at https://www.sworm.gov/about.htm).

[11] National Science and Technology Council, *National Space Weather Strategy*, Washington, DC, October 2015.

[12] E.O. 13744, "Coordinating Efforts to Prepare the Nation for Space Weather Events," 81 *Federal Register* 71573-71577, October 18, 2016.

[13] National Science and Technology Council, *National Space Weather Strategy and Action Plan*, Washington, DC, March 2019.

[14] E.O. 13865, "Coordinating National Resilience to Electromagnetic Pulses," 84 *Federal Register* 12041-12046, March 29, 2019.

Additionally, it defined GMDs as a subset of EMP—a definition with potential policy implications (see "Additional Considerations").

In 2020, President Trump released "The National Space Policy," superseding the 2010 version and reemphasizing other space-related guidance.[15] Among other topics, the policy expanded NASA and NOAA's space weather responsibilities from the 2010 policy, and reiterated OSTP's role in implementing the 2019 Plan.

1995–2020 Chronology of Space Weather Federal Coordination

1995	NSWP is established under Department of Commerce auspices, and directed by the NSWP Council.
2010	Congress directs OSTP to improve national preparedness for space weather events.
2010	President Obama releases the "National Space Policy of the United States of America."
2014	NSTC establishes the Space Weather Operations, Research, and Mitigation (SWORM) Working Group.
2015	The SWORM Interagency Working Group publishes the "National Space Weather Strategy."
	The NSWP Council is deactivated.[16]
2016	President Obama signs Executive Order (E.O.) 13744, "Coordinating Efforts to Prepare the Nation for Space Weather Events."
2019	The SWORM Interagency Working Group releases updated national space weather strategy, "The National Space Weather Strategy and Action Plan."
	President Trump signs E.O. 13865, "Coordinating National Resilience to Electromagnetic Pulses."
2020	President Trump releases "The National Space Policy."
	Congress directs federal agencies to work together in certain ways, including instructing NSTC to establish the Space Weather Interagency Working Group.

Taken together, the 2019 Plan and E.O. 13865 prioritize investment in CI resilience initiatives over scientific research and forecasting, and represent a shift in policy from what the Obama Administration set forth in the 2015 Strategy and E.O 13744.[17] The 2019 Plan focuses on three objectives related to protection of assets, space weather forecasting, and planning for space weather events, and identifies the agencies and departments with responsibilities under each objective (**Figure 2**). E.O. 13865 also directs relevant federal agencies to identify regulatory and cost-recovery mechanisms that the government may use to compel private-sector investments in resilience.[18] This approach differs from most other federal infrastructure resilience initiatives, which generally rely upon voluntary industry adoption of resilience measures.[19]

Implementation of the 2019 order has included individual department and agency actions, as well as interagency efforts. For example, an interagency working group of the National Science and

[15] Executive Office of the President, "The National Space Policy," 85 *Federal Register* 81755, December 9, 2020.

[16] Bonadonna 2016.

[17] E.O. 13865 uses the USA PATRIOT Act (P.L. 107-56) definition of critical infrastructure: systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters.

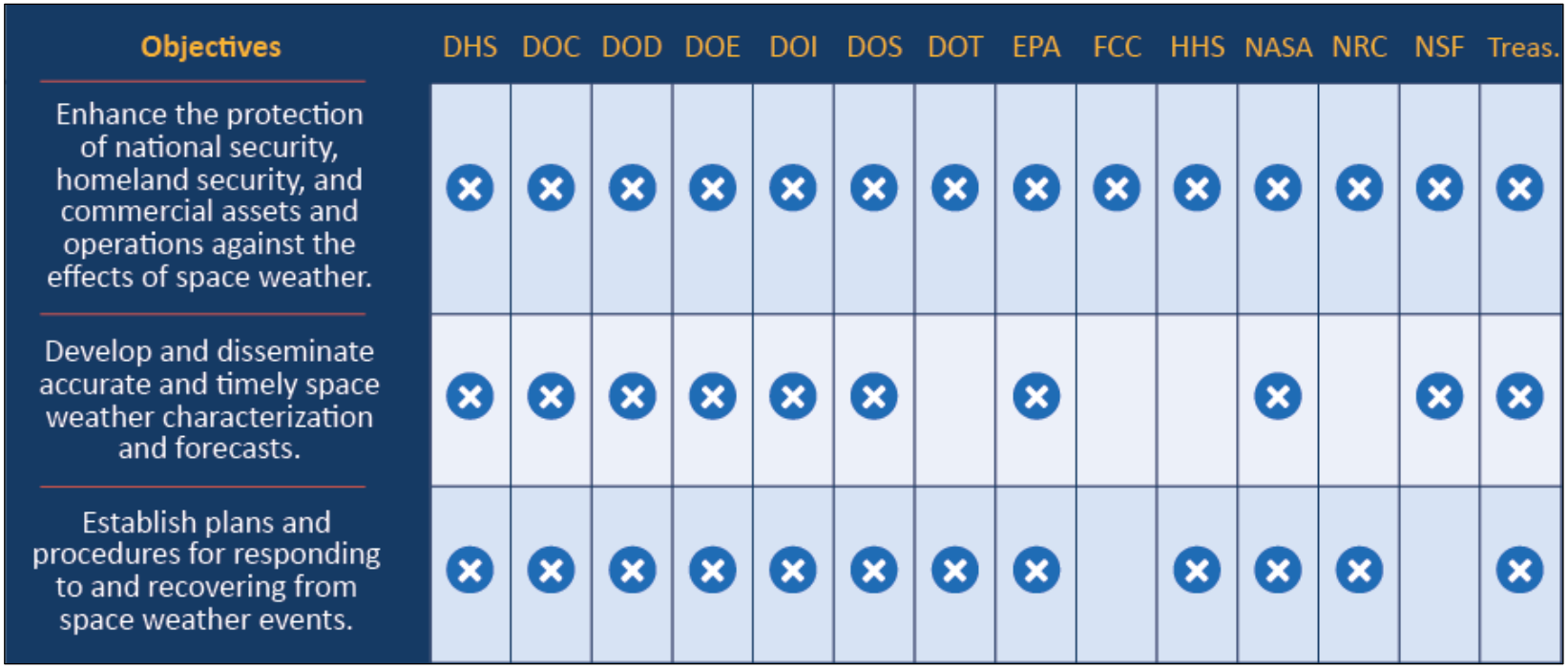
[18] E.O. 13865, Section 6c(iii).

[19] See CRS Report R45809, *Critical Infrastructure: Emerging Trends and Policy Considerations for Congress*, by Brian E. Humphreys.

Technology Council has identified space weather observational R&D needs in line with multiple departmental and agency executive order responsibilities and core mission areas.[20]

[20] Electromagnetic Pulse Research and Development Assessment Interagency Working Group, *Research and Development Needs for Improving Resilience to Electromagnetic Pulses*, June 2020, p. 12, at https://trumpwhitehouse.archives.gov/wp-content/uploads/2017/12/Research-Development-Needs-For-Improving-Resilience-to-Electromagnetic-Pulses-June-2020.pdf.

Figure 2. 2019 National Space Weather Strategy and Action Plan Objectives by Agency



Source: CRS from National Science and Technology Council, *National Space Weather Strategy and Action Plan*, Washington, DC, March 2019.

Notes: DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOI = Department of the Interior; DOS = Department of State; DOT = Department of Transportation; EPA = Environmental Protection Agency; FCC = Federal Communications Commission; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NRC = Nuclear Regulatory Commission; NSF = National Science Foundation; and Treas. = Department of the Treasury. Not all federal departments and agencies listed in the figure are discussed in this report.

Space Weather-Related Legislation Enacted in the 116th and 117th Congresses

The 116th Congress considered and passed two bills related to space weather research, forecasting, preparedness, response, and recovery. Both bills direct multiple federal departments and agencies to support new and existing space weather-related activities. Some of the provisions enacted certain parts of existing executive orders, which may lead to questions on agency implementation when those directives are potentially unclear or overlap (see "Additional Considerations").

The National Defense Authorization Act for Fiscal Year 2020 (P.L. 116-92)

In December 2019, Congress enacted the National Defense Authorization Act for Fiscal Year 2020 (FY2020 NDAA; P.L. 116-92). The FY2020 NDAA amended the Homeland Security Act of 2002 (P.L. 107-296) and contains a series of homeland security-related requirements that parallel the E.O. 13865 framework for critical infrastructure resilience and emergency response. **Table 1** contains this information.[21]

Table 1. Summary of Space Weather or EMP-Related Requirements in FY2020 NDAA

Department or Agency	Requirement	Deadline	Status
Agencies supporting National Essential Functions[a]	Update operational plans to protect against and mitigate effects of EMP/GMD	March 20, 2020	DOE stated that its updated "response plans, programs, and procedures and operational plans all account for the effects of EMP and GMD."[b]
DHS (relevant sector-specific agencies)	Submit R&D Action Plan to Congress	March 26, 2020	Pending.
DHS, DOD, DOE, DOC	Brief Quadrennial Risk Assessment to Congress	March 26, 2020	Delayed to end of FY2021.
DHS	Provide information on EMP/GMD to federal, state, local, and private sector stakeholders	June 19, 2020	Ongoing through existing programs and activities.

[21] Agency-provided information to CRS is current as of March 8, 2021. CRS research librarians Rachael Roan and Alexandra Kosmidis searched public sources on March 29, 2022, to update agency-provided information where possible. CRS has not independently verified this information. Terms searched: electromagnetic pulse, EMP, geomagnetic disturbance, GMD, space weather, Quadrennial Risk Assessment, R&D Action Plan, emergency notification systems, technological capabilities, and technological gaps. Sources searched: press releases and annual reports for DHS, DOC, DOD, DOE, DOT, FCC, FEMA, FERC, CISA, and Los Alamos National Laboratory; *Congressional Record* and *Committee Reports* on Congress.gov; Inside Defense: https://insidedefense.com/; Google searches across .gov and .mil domains.

Department or Agency	Requirement	Deadline	Status
FEMA (CISA, DOE, FERC)	Develop EMP/GMD response and recovery plans and procedures	June 19, 2020	Ongoing compliance via existing plans and procedures.
DHS (S&T, CISA, FEMA, DOD, DOE)	Pilot test of engineering approaches to mitigate EMP/GMD effects	September 22, 2020	Under contract with Los Alamos National Laboratory (LANL) for completion by July 2021.
DOD (DHS, DOE)	Pilot test of engineering approaches to harden defense installations and associated infrastructure	September 22, 2020	Interagency pilot project in San Antonio, TX, ongoing. Additional work pending completion of LANL pilot test of engineering approaches.
FEMA (CISA, DOE, FERC)	Conduct EMP/GMD national exercise	December 21, 2020	Completed in December 2020.
DHS (FEMA, CISA, DOD, DOC, FCC, DOT)	Report to Congress on effects of EMP/GMD on communications infrastructure with recommendations for changes to operational response plans	December 21, 2020	Vulnerability assessment of priority infrastructure ongoing (scheduled completion July 2021). Report expected January 2022.
FEMA	Brief Congress on state of emergency notification systems	December 21, 2020	Complied via briefing to House Energy and Commerce Committee on November 2, 2020.
DHS (DOD, DOE)	Report on technological capabilities and gaps	December 21, 2020	Report draft complete. Agency review ongoing.
DHS (sector-specific agencies, DOD, DOE)	Review test data on EMP/GMD effects on critical infrastructure	December 21, 2020	No information provided.

Source: FY2020 NDAA (P.L. 116-92), Section 1740 and email correspondence on March 8, 2021, with James Platt, Strategic Defense Initiatives, EMP/PNT/GMD Space Weather/Space Risks, National Risk Management Center, CISA, and CRS search of public sources.

Note: Parentheses in the first column denote a coordination requirement for the lead department or agency (in bold). CISA = Cybersecurity and Infrastructure Security Agency (a part of DHS); DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOT = Department of Transportation; EMP = electromagnetic pulse; FCC = Federal Communications Commission; FEMA = Federal Emergency Management Agency (a part of DHS); FERC = Federal Energy Regulatory Commission (an independent regulatory commission within DOE); GMD = geomagnetic disturbance; R&D = research and development; S&T = Science and Technology Directorate (a part of DHS).

a. National Essential Functions are defined in the bill as "the overarching responsibilities of the Federal Government to lead and sustain the Nation before, during, and in the aftermath of a catastrophic emergency, such as an EMP or GMD that adversely affects the performance of the Federal Government."

b. U.S. Department of Energy, Agency Financial Report Fiscal Year 2020, DOE/CF-0170, November 2020, pp. 11-12, at https://www.energy.gov/sites/prod/files/2020/11/f80/fy-2020-doe-agency-financial-report.pdf.

The Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act (P.L. 116-181)

In October 2020, Congress enacted the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act (PROSWIFT Act; P.L. 116-181; 51 U.S.C. §§60601-60608), which directed multiple federal entities, including OSTP, NOAA, NASA, the National Science Foundation (NSF), the U.S. Geological Survey (USGS), and parts of the Department of Defense (DOD), to improve space weather forecasts and predictions. The act repealed the space weather-related provision in P.L. 111-267; replacing it with similar language directing OSTP to coordinate federal activities to "improve the ability of the United States to prepare for, avoid, mitigate, respond to, and recover from potentially devastating impacts of space weather." OSTP is also directed, in collaboration with the interagency working group described below and NOAA-administered advisory group described below, to develop and periodically update a strategy for coordinated observations of space weather by the working group federal agencies.[22] The PROSWIFT Act builds on E.O. 13744, using similar language that enacts several of the executive order's key provisions as well as elements of the 2019 Plan that have provided policy guidance for federal agencies.

In addition to agency-specific requirements, the PROSWIFT Act directs the National Science and Technology Council (NSTC) to establish a space weather interagency working group to include representatives from NOAA, NASA, NSF, DOD, the Department of the Interior, and "such other federal agencies as the Director of [OSTP] deems appropriate."[23] The PROSWIFT Act directs the group to "coordinate executive branch actions that improve the understanding and prediction of and preparation for space weather phenomena, and coordinate [f]ederal space weather activities."[24] Other provisions direct the working group to (1) develop, submit to certain congressional committees, and make public a plan to implement the OSTP-coordinated strategy,[25] (2) craft formal mechanisms to ensure transition of research to operations and communicate operational needs to research,[26] and (3) review and update NSTC's space weather benchmarks.[27] After enactment, NOAA determined that the existing SWORM Interagency Working Group fulfills the act's requirement to establish an interagency working group.[28]

The PROSWIFT Act also lists individual and shared requirements for certain agencies. (See each department/agency section below for summary of agency-specific provisions.)

As enacted, the PROSWIFT Act did not include provisions from earlier versions of the legislation that would have directed the National Security Council to "assess the vulnerability of the national security community to space weather events" and to develop national security mechanisms to

[22] 51 U.S.C. 60602(a)(b), and (e).

[23] 51 U.S.C. §60601(c).

[24] 51 U.S.C. §60601(c). In March 2022, NTSC published an interagency framework to support space weather-related research-to-operations and operations-to-research processes in partial fulfilment of the statutory mandate and certain executive branch directives, including E.O. 13744. See NSTC (SWORM), *Space Weather Research-to-Operations and Operations-to-Research Framework*, Washington, DC, March 2022, https://www.sbir.gov/node/2120223.

[25] 51 U.S.C. §60602(d).

[26] 51 U.S.C. §60604(d).

[27] 51 U.S.C. §60608.

[28] Email communication with NOAA Office of Legislative and Intergovernmental Affairs (OLIA), September 14, 2021.

protect national security assets from space weather threats.[29] In a signing statement, President Trump wrote that some provisions of the PROSWIFT Act were "unobjectionable," but that the act did not address "the resilience of national security assets or critical infrastructure to the effects of space weather" and unduly limited his authority to conduct foreign affairs.[30]

Legislation in the 117th Congress

The Consolidated Appropriations Act, 2022 (P.L. 117-103) continues support for maintenance and modernization of satellites used for space-weather forecasting. In addition, the Infrastructure Investment and Jobs Act (IIJA; P.L. 117-58) authorizes $50 million for creation of an "advanced energy security program" to support modeling of risks posed by natural and human-made threats and hazards, including electromagnetic pulse and geomagnetic disturbance. Other eligible activities include grid resilience exercises and assessments, research on grid hardening solutions, mitigation and recovery, and "technical assistance to States and other entities for standards and risk analysis."[31] IIJA also appropriates $157.5 million in research and development funding to the Science and Technology Directorate of DHS for a variety of purposes, including "electromagnetic pulse and geomagnetic disturbance resilience capabilities."[32] DHS is required to submit a detailed spend plan for research and development appropriations made under this provision within 90 days of enactment.

Select Department and Agency Roles and Responsibilities

This section provides an overview of federal roles and responsibilities for space weather-related research and emergency preparedness under current legislation and executive branch policy guidance. Legislative or executive branch directives applicable only to human-made EMP threats, such as high-altitude nuclear detonations, are excluded from this overview.

Federal agency roles and responsibilities fall into five major categories: early warning and forecasting; research and development (R&D); basic scientific research; risk assessment and mitigation, including modeling and information sharing; and response and recovery. Some agencies have roles and responsibilities in more than one category. This section includes only entities that relevant legislation, executive orders, or national strategies have designated as the federal lead for a specific objective or requirement. Therefore, agencies whose role is confined to participation in working groups, harmonizing internal policies with national strategy or directives, contributing refinements to analytical products or models produced by other agencies, or ensuring their own continuity-of-operations in case of a space weather event are not included.

Each subsection includes a summary of the department or agency mission and the relevant authorities under which it operates.[33] If applicable, the agency-specific provisions of the two executive orders currently in force—E.O. 13744 and E.O. 13865—are listed in a table, followed by information about implementing programs and activities. The 2019 Plan is referenced in cases where the executive orders do not provide specific or complete guidance to given federal entities.

[29] S. 881 introduced in the Senate, March 26, 2019.

[30] The White House, "Signing Statement from President Donald J. Trump on S. 881," release, October 21, 2020, https://www.whitehouse.gov/briefings-statements/signing-statement-president-donald-j-trump-s-881/.

[31] See P.L. 117-58, Sec. 40125(d)(2).

[32] See P.L. 117-58, Division J, Title V.

[33] Departments and agencies are ordered alphabetically for ease of reference.

In addition, each subsection lists agency-specific requirements of the FY2020 NDAA and the PROSWIFT Act that affect previously existing program authorities for a given department or agency.

Department of Commerce[34]

In 1988, Congress authorized the Secretary of Commerce to "prepare and issue predictions of electromagnetic wave propagation conditions and warnings of disturbances in such conditions."[35] The Secretary of Commerce delegated those responsibilities to the National Oceanic and Atmospheric Administration (NOAA). The Secretary of Commerce also directed NOAA to fulfill the department's space weather responsibilities in 2016 under E.O. 13744 and in 2019 under E.O. 13865 (**Table 2**).

Table 2. Responsibilities of the Secretary of Commerce Under E.O. 13744 and E.O. 13865

E.O. 13744	E.O. 13865
"(i) provide timely and accurate operational space weather forecasts, watches, warnings, alerts, and real-time space weather monitoring for the government, civilian, and commercial sectors, exclusive of the responsibilities of the Secretary of Defense; and (ii) ensure the continuous improvement of operational space weather services, utilizing partnerships, as appropriate, with the research community, including academia and the private sector, and relevant agencies to develop, validate, test, and transition space weather observation platforms and models from research to operations and from operations to research."	"(i) provide timely and accurate operational observations, analyses, forecasts, and other products for natural EMPs, and (ii) use the capabilities of the Department of Commerce, the private sector, academia, and nongovernmental organizations to continuously improve operational forecasting services and develop standards for commercial EMP technology."

Source: Executive Order 13744, "Coordinating Efforts to Prepare the Nation for Space Weather Events," 81 *Federal Register* 71573, October 18, 2016, and Executive Order 13865, "Coordinating National Resilience to Electromagnetic Pulses," 84 *Federal Register* 12043, March 29, 2019.

Both executive orders direct the Secretary to improve services and collaborate with relevant stakeholders. The 2016 order refers to the hazard of concern as space weather, while the 2019 order refers to it as natural EMPs. The FY2020 NDAA does not include directives for the Department of Commerce; PROSWIFT Act provisions are described below. The Department of Commerce's space weather programs and activities are concentrated in NOAA. The National Institute for Standards and Technology (NIST), another agency within the Department of Commerce, indicated that it has supported "important calibrations that enable systems to operate in space and meet important performance criteria for other agencies."[36]

[34] For more information, contact Eva Lipiec, Analyst in Natural Resources Policy.

[35] P.L. 100-418, Title V; 15 U.S.C. §1532.

[36] Email correspondence between CRS and NIST Office of Congressional and Legislative Affairs, January 26 and 28, 2021.

National Oceanic and Atmospheric Administration (NOAA)

NOAA's space weather work falls primarily under two line offices: National Weather Service (NWS) and National Environmental Satellite, Data, and Information Service (NESDIS).[37] NWS operates and maintains observing systems to support forecasting of space weather, including the National Solar Observatory Global Oscillation Network Group, a series of ground-based observatories.[38] NWS also operates the Space Weather Prediction Center, which provides real-time monitoring and forecasting of solar events and disturbances and develops models to improve understanding and predict future events.[39] NESDIS maintains NOAA's space weather data through the National Centers for Environmental Information.[40] It also develops and manages several satellite programs, which collect solar and space weather-related observations, including the Geostationary Operational Environmental Satellites (GOES) and the Space Weather Follow-on program.[41]

The PROSWIFT Act requires the NOAA Administrator to establish a space weather advisory group (SWAG) of stakeholders from the academic, commercial space weather, and space weather end user communities.[42] NOAA established SWAG in 2021; the group held its first meeting in December 2021.[43]

The act allows interagency working group members to enter into agreements with one another and requires NOAA to enter into agreements with NASA to develop "space weather spacecraft, instruments, and technologies," while maintaining existing capabilities in the interim. [44] NOAA also is required to develop a contingency plan for space weather forecasting in the event that existing space-based assets fail prior to replacement and brief Congress on its plan, and "should" develop space-based capabilities beyond the baseline capabilities, with the potential to work with commercial and academic communities.[45] NOAA has indicated it has entered into interagency agreements with NASA and DOD, continues to maintain existing back-up capabilities and plan for those of the future, and is exploring partnerships with NASA, NSF, DOD, and the international space agency and research communities to support research and ensure back-up and space-based observational capabilities.[46]

[37] NOAA, "Budget Estimates, Fiscal Year 2021," at https://www.commerce.gov/sites/default/files/2020-02/fy2021_noaa_congressional_budget_justification.pdf.

[38] National Solar Observatory, "Global Oscillation Network Group," at https://gong.nso.edu/.

[39] NOAA Space Weather Prediction Center, "Space Weather Conditions," at https://www.swpc.noaa.gov/.

[40] NOAA National Centers for Environmental Information, "Space Weather," at https://www.ngdc.noaa.gov/stp/spaceweather.html.

[41] NOAA, "Geostationary Operational Environmental Satellites—R Series," at https://www.goes-r.gov/ and NOAA Office of Projects, Planning and Analysis, "Space Weather Follow-On," at https://www.nesdis.noaa.gov/OPPA/swfo.php.

[42] 51 U.S.C. §60601(d). For more information about the PROSWIFT Act, see the section entitled "The Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act."

[43] NOAA, "Establishment of the Space Weather Advisory Group and Solicitation of Nominations for Membership," 86 *Federal Register* 24390, May 6, 2021, and NOAA, National Weather Service, "Space Weather Advisory Group (SWAG)," at https://www.weather.gov/swag.

[44] 51 U.S.C. §60601(c)(2), 51 U.S.C. §60603(b)(3), and 51 U.S.C. §60603(c).

[45] 51 U.S.C. §60603(d), 51 U.S.C. §60603(e), 51 U.S.C. §60603(i), and 51 U.S.C. §60604(b)(3).

[46] Email communication with NOAA OLIA, August 6, 2021.

The PROSWIFT Act also directs NOAA to support review of the integrated strategy and associated research and development goals,[47] and to provide for broad-based information sharing with key stakeholders.[48] As of August 2021, NOAA continues to work to inform the strategy and expects to enter into an agreement with the National Academies of Sciences, Engineering, and Medicine (NASEM) to review the strategy in 2023.[49] NOAA indicated that it provides near real-time space weather-related data freely and that it has entered into an agreement with NASEM to establish the Government-University-Commercial Roundtable on Space Weather.[50] The act also requires NOAA to establish and administer a pilot program to obtain commercial sector space weather data.[51] NOAA solicited commercial space weather data in September 2020, but according to NOAA, none of the responses met NOAA's mission needs; [52] in November 2021 the agency released another request for information on existing and planned commercial space-based space weather data and related capabilities.[53] The FY2020 NDAA does not contain specific provisions addressing the roles and responsibilities of NOAA regarding EMPs/GMDs.

Department of Defense (DOD)[54]

E.O. 13744 directed DOD to provide space weather forecasts and related products to support military operations of the United States and its partners (**Table 3**).

[47] 51 U.S.C. §60602(c).

[48] 51 U.S.C. §60605(b) and 51 U.S.C. §60606.

[49] Email communication with NOAA OLIA, August 6, 2021.

[50] Email communication with NOAA OLIA, August 6, 2021.

[51] 51 U.S.C. §60607.

[52] Email communication with NOAA OLIA, August 6, 2021.

[53] NOAA, Office of Space Commerce, "NOAA Commercial Space Weather Data RFI," at https://www.space.commerce.gov/noaa-commercial-space-weather-data-rfi/.

[54] For more information, contact Stephen McCall, Analyst in Military Space, Missile Defense, and Defense Innovation.

Table 3. Responsibilities of the Secretary of Defense Under E.O. 13744 and E.O. 13865

E.O. 13744	E.O. 13865
"(a) The Secretary of Defense shall ensure the timely provision of operational space weather observations, analyses, forecasts, and other products to support the mission of the Department of Defense and coalition partners, including the provision of alerts and warnings for space weather phenomena that may affect weapons systems, military operations, or the defense of the United States."	"(i) in cooperation with the heads of relevant agencies and with United States allies, international partners, and private-sector entities as appropriate, improve and develop the ability to rapidly characterize, attribute, and provide warning of EMPs, including effects on space systems of interest to the United States; (ii) provide timely operational observations, analyses, forecasts, and other products for naturally occurring EMPs to support the mission of the Department of Defense along with United States allies and international partners, including the provision of alerts and warnings for natural EMPs that may affect weapons systems, military operations, or the defense of the United States; (iii) conduct R&D and testing to understand the effects of EMPs on Department of Defense systems and infrastructure, improve capabilities to model and simulate the environments and effects of EMPs, and develop technologies to protect Department of Defense systems and infrastructure from the effects of EMPs to ensure the successful execution of Department of Defense missions; (iv) review and update existing EMP-related standards for Department of Defense systems and infrastructure, as appropriate; (v) share technical expertise and data regarding EMPs and their potential effects with other agencies and with the private sector, as appropriate."

Source: Executive Order 13744, "Coordinating Efforts to Prepare the Nation for Space Weather Events," 81 *Federal Register* 71573, October 18, 2016; and Executive Order 13865, "Coordinating National Resilience to Electromagnetic Pulses," 84 *Federal Register* 12042-12043, March 29, 2019.

The National Defense Authorization Act for Fiscal Year 2018 (FY2018 NDAA; P.L. 115-91) codified the language in E.O. 13744. According to the FY2018 NDAA

> It is the sense of Congress that the [Secretary of Defense] should ensure the timely provision of operational space weather observations, analyses, forecasts, and other products to support the mission of the DOD including the provision of alerts and warnings for space weather phenomena that may affect weapons systems, military operations, or the defense of the United States.

E.O. 13865 reiterates the E.O. 13744 requirement verbatim, except that it substitutes the phrase "naturally occurring EMPs" for "space weather phenomena." E.O. 13865 also directs DOD to take further steps related to EMP characterization, warning systems, effects, and protection of DOD systems and infrastructure and the United States from EMPs.

The FY2020 NDAA requires DOD to provide quadrennial EMP and GMD risk assessment briefings to Congress, pilot test engineering approaches to harden defense installations and

associated infrastructure from the effects of EMPs and GMDs by September 22, 2020,[55] and coordinate with other departments and agencies on related activities (**Table 1**).

DOD is also a member of the interagency working group created by the PROSWIFT Act. The act directs DOD, among other departments and agencies, to continue to carry out basic research on heliophysics, geospace science, and space weather, as well as support competitive proposals for research, modeling, and monitoring of space weather.[56] NASA, NSF, and USGS are also required to transition "space weather research findings, models, and capabilities" to DOD and NOAA, subject to consultation with a designated stakeholder advisory group.[57] Also under the PROSWIFT Act, the Secretaries of the Air Force and Navy are requires to maintain and improve ground-based observations of the sun to meet user needs and to continue to provide space weather data through ground-based facilities.[58]

Air Force

The U.S. Air Force is the lead for all DOD and Intelligence Community (IC) space weather information.[59] Air Force weather personnel provide space environmental information, products, and services required to support DOD operations as required.[60] Air Force space weather operations and capabilities are to support all elements of the DOD and its decisionmakers. The Congressional Budget Office (CBO) estimates that the Department of Defense, primarily the Air Force, allocated $24 million to space weather activities in FY2019.[61]

The 557th Weather Wing, located at Offutt Air Force Base, Nebraska, conducts most of DOD's space weather-related activities. (The 557th Weather Wing remains under the U.S. Air Force rather than the U.S. Space Force). It uses ground-based and space-based observing systems, including the Solar Electro-optical Observing Network (SEON), a network of ground-based observing sites providing 24-hour coverage of solar phenomena; ground-based ionosondes and other sensors providing data in the ionosphere; and space-based observations from the Defense Meteorological Satellite Program.[62]

Army

The Army has two full-time meteorologists to coordinate space weather support within the Army and with other DOD and federal agencies.

[55] 6 U.S.C. 195f(d)(1)(E)(ii) and P.L. 116-92, Section 1740(f).

[56] 51 U.S.C. 60604(a).

[57] 51 U.S.C. 60604(d).

[58] 51 U.S.C. 60603(f).

[59] Department of Defense Joint Publication 3-14, *Space Operations*, April 10, 2018, at https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_14.pdf.

[60] Office of the Federal Coordinator for Meteorological Services and Supporting Research, *The Federal Plan for Meteorological Services and Supporting Research—Fiscal Year 2017*, FCM-P1-2016, at http://www.ofcm.gov/publications/fedplan/FCM-p1-2017.pdf.

[61] Email communication between CRS and Robert Reese, Congressional Budget Office, on October 1, 2019.

[62] Office of the Federal Coordinator for Meteorological Services and Supporting Research, *The Federal Plan for Meteorological Services and Supporting Research—Fiscal Year 2017*, pp. 2-174 to 2-175.

Navy

The Naval Research Laboratory's (NRL's) Remote Sensing and Space Science Divisions and the Naval Center for Space Technology also contribute to the DOD's space weather activities.[63] For example, the Wide-field Imager for Solar Probe Plus (WISPR), launched in August 2018, was designed and developed for NASA by NRL's Space Design Division. WISPR determines the fine-scale electron density and velocity structure of the solar corona and the source of shocks that produce solar energetic particles.[64]

Department of Energy (DOE)[65]

DOE is responsible for monitoring and assessing the potential disruptions to energy infrastructure from space weather, and for coordinating electricity restoration under authorities granted to it by the White House and Congress.[66]

Table 4. Responsibilities of the Secretary of Energy Under E.O. 13744 and E.O. 13865

E.O. 13744	E.O. 13865
(i) "shall facilitate the protection and restoration of the reliability of the electrical power grid during a presidentially declared grid security emergency associated with a geomagnetic disturbance pursuant to 16 U.S.C. 824o-1."	(i) "shall conduct early-stage R&D, develop pilot programs, and partner with other agencies and the private sector, as appropriate, to characterize sources of EMPs and their couplings to the electric power grid and its subcomponents, understand associated potential failure modes for the energy sector, and coordinate preparedness and mitigation measures with energy sector partners."

Source: Executive Order 13744, "Coordinating Efforts to Prepare the Nation for Space Weather Events," 81 *Federal Register* 71573, October 18, 2016, and Executive Order 13865, "Coordinating National Resilience to Electromagnetic Pulses," 84 *Federal Register* 12043, March 29, 2019.

E.O. 13744 directs DOE to protect and restore the electric power grid in the event of a presidentially declared grid emergency associated with a geomagnetic disturbance. E.O. 13865 assigns additional roles and responsibilities to DOE specific to R&D and coordination with the private sector to better understand electromagnetic threats and hazards, and their possible effects on the electric power grid (**Table 4**). The FY2020 NDAA directs the Secretary of Energy to provide quadrennial EMP and GMD risk assessment briefings to Congress,[67] as well as to coordinate with other departments and agencies on related activities. The Secretary of Energy may also develop or update benchmarks that describe the physical characteristics of EMPs to be shared with CI owners and operators.[68] DOE stated that it "made progress on a number of

[63] U.S. Navy, "NRL Sensor Provides Critical Space Weather Observations," at http://www.navy.mil/submit/display.asp?story_id=49408; and U.S. Navy, "NRP Brings New Hyperspectral Atmospheric and Ocean Science to ISS," at http://www.navy.mil/submit/display.asp?story_id=48197.

[64] U.S. Naval Research Laboratory, "Headlines and Areas of Research," at https://www.nrl.navy.mil/ssd/overview/areas-of-research.

[65] For more information, contact Richard J. Campbell, Specialist in Energy Policy.

[66] The White House, "Critical Infrastructure Security and Resilience," Presidential Policy Directive 21, February 12, 2013. P.L. 114-94 enacted into law the designation of DOE as the sector-specific agency for the energy sector (6 U.S.C. §121 note).

[67] 6 U.S.C. 195f(d)(E)(ii).

[68] 6 U.S.C. 195f note.

actions" under E.O. 13865 and the FY2020 NDAA, but did not specify which DOE agencies and offices had led the efforts.[69] The PROSWIFT Act does not contain specific energy infrastructure protection requirements or explicitly name DOE as a member of the interagency working group; however, DOE is a part of the existing SWORM Interagency Working Group.[70]

Relevant programs and activities for energy infrastructure protection and threat mitigation are led by the DOE's Office of Cybersecurity, Energy Security, and Emergency Response (CESER), the Federal Energy Regulatory Commission (FERC), the North American Electric Reliability Corporation (NERC), and DOE's national laboratories.

Office of Cyber Security, Energy Security, and Emergency Response (CESER)

In February 2018, DOE announced the creation of CESER.[71] CESER has two main divisions: Infrastructure Security and Energy Restoration (ISER), and Cybersecurity for Energy Delivery Systems. ISER's mission is "to secure U.S. energy infrastructure against all hazards, reduce the impact of disruptive events, and respond to and facilitate recovery from energy disruptions, in collaboration with the private sector and state and local governments."[72]

DOE has produced a number of reports on GMDs and EMPs. In compliance with the National Space Weather Action plan, ISER produced a 2019 report on geomagnetic disturbances and the impact on the electricity grid.[73] This report was designed to provide a better understanding of GMD events in order to protect the U.S. electricity grid.

Prior to the reorganization, DOE's OE collaborated with the Electric Power Research Institute (EPRI), a nonprofit organization that conducts research and develops projects focused on electricity. In 2016, the OE and EPRI together developed the *Joint Electromagnetic Pulse Resilience Strategy*, and subsequently the *DOE Electromagnetic Pulse Resilience Action Plan* in January 2017. E.O. 13865 refers to EMPs in two categories: human-made high-altitude (HEMP) and natural EMPs—often referred to as GMDs by government agencies. These DOE-EPRI documents focus specifically on human-made nuclear threats and categorize GMDs separately from EMPs.[74] However, the 2017 plan notes that "many of the actions proposed herein ... are also relevant to geomagnetic disturbances (GMD), which are similar in system interaction and effects to the E3 portion of the nuclear EMP waveform."[75]

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[69] Stated activities included "identifying critical equipment and systems; preparing unclassified waveforms for partner use; working so that DOE's response plans, programs, and procedures and operational plans all account for the effects of EMP and GMD testing equipment to identify vulnerabilities; and implementing pilot programs" (U.S. Department of Energy, *Agency Financial Report Fiscal Year 2020*, DOE/CF-0170, November 2020, pp. 11-12, https://www.energy.gov/sites/prod/files/2020/11/f80/fy-2020-doe-agency-financial-report.pdf). The FY2021 agency report does not make reference to these or any other related activities. (U.S. Department of Energy, Agency Financial Report Fiscal Year 2021, DOE/CF-0180, November 2021, https://www.energy.gov/sites/default/files/2021-11/fy-2021-doe-agency-financial-report_0.pdf)

[70] SWORM, "About SWORM," at https://www.sworm.gov/about.htm.

[71] DOE, "The CESER Blueprint," at https://www.energy.gov/ceser/ceser-blueprint.

[72] U.S. Department of Energy, "Office of Cybersecurity, Energy Security and Emergency Response," at https://www.energy.gov/ceser/ceser-mission.

[73] U.S. Department of Energy, *Geomagnetic Disturbance Monitoring Approach and Implementation Strategies,* January 2019.

[74] U.S. Department of Energy, *U.S. Department of Energy Electromagnetic Pulse Resilience Action Plan,* January 2017. Hereinafter U.S. Department of Energy 2017.

[75] U.S. Department of Energy 2017, p. 3.

Federal Energy Regulatory Commission (FERC)

FERC is an independent government agency officially organized as part of DOE.[76] The Energy Policy Act of 2005 (EPAct05; P.L. 109-58) authorized FERC to oversee the reliability of the bulk-power system.[77] FERC's jurisdiction is limited to the wholesale power market and the transmission of electricity in interstate commerce.

EPAct05 authorized the creation of an electric reliability organization (ERO) to establish and enforce national reliability standards subject to FERC oversight.[78] FERC certified NERC as the ERO in 2006. The ERO authors the standards for critical infrastructure protection. These standards, which FERC can approve or remand back, are mandatory and enforceable (with fines potentially over $1 million/day for noncompliance).[79] In November 2018, FERC issued a final rule on reliability and transmission system performance standards for GMDs directing NERC to develop "corrective action plans" to mitigate GMD vulnerabilities, and to authorize time extensions to implement "corrective action plans" on a case-by-case basis.[80] Additionally, the final rule accepts the ERO's submitted research plan on GMDs.

North American Electric Reliability Corporation (NERC)

In 2006 FERC certified NERC as the ERO for the United States. NERC works closely with public and private electric utilities to develop and enforce FERC-approved standards.[81] Part of NERC's role includes reducing risks and vulnerabilities to the bulk-power system. In April 2019, NERC created a task force in response to E.O. 13865 to examine potential vulnerabilities associated with EMPs and to develop possible areas for improvement, focusing on nuclear EMP threats.[82]

National Laboratories

The 17 DOE national laboratories advance research and development to support DOE's mission. For example, Los Alamos National Laboratory has funded work on an ongoing study of EMP and GMD physical characteristics and effects on critical infrastructure.[83]

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[76] Federal Energy Regulatory Commission, "History of FERC," at https://www.ferc.gov/students/ferc/history.asp?csrt=4360715013901212967.

[77] Defined by NERC as "(A) facilities and control systems necessary for operating an interconnected electric energy transmission network (or any portion thereof); and (B) electric energy from generation facilities needed to maintain transmission system reliability. The term does not include facilities used in the local distribution of electric energy." NERC, *Glossary of Terms Used in NERC Reliability Standards,* May 13, 2019, at https://www.nerc.com/files/glossary_of_terms.pdf.

[78] North American Electric Reliability Corporation, "History of NERC," at https://www.nerc.com/news/Documents/HistoryofNERC01JUL19.pdf.

[79] For more information on FERC, see CRS Report R45312, *Electric Grid Cybersecurity*, by Richard J. Campbell.

[80] Geomagnetic Disturbance Reliability Standard; Reliability Standard for Transmission System Planned Performance for Geomagnetic Disturbance Events, Order no. 851, 165 FERC ¶ 61,124 (2018).

[81] NERC is required to submit an assessment of its performance to FERC three years from the date of certification as the ERO and every five years thereafter. North American Electric Reliability Corporation, "ERO Performance Assessment," at https://www.nerc.com/gov/Pages/Three-Year-Performance.aspx.

[82] NERC, "Electromagnetic Pulses Task Force, Background," at https://www.nerc.com/pa/Stand/Pages/EMPTaskForce.aspx.

[83] See Michael Rivera, Scott Backhaus, and Jesse Woodroffe, et al., *EMP/GMD Phase 0 Report, A Review of EMP Hazard Environments*, Los Alamos National Laboratory, LA-UR-16-28380, Los Alamos, NM, October 24, 2016, at https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-16-28380. The last update on the research was

Department of Homeland Security (DHS)[84]

Under Presidential Policy Directive 21 (PPD-21), DHS is the lead U.S. agency for critical infrastructure protection and disaster preparedness.[85] E.O. 13744 and E.O. 13865 assign several roles and responsibilities to DHS specific to space weather and EMPs (**Table 5**).

Table 5. Responsibilities of the Secretary of Homeland Security Under E.O. 13744 and E.O. 13865

E.O. 13744	E.O. 13865
"(i) ensure the timely redistribution of space weather alerts and warnings that support national preparedness, continuity of government, and continuity of operations; and	"(i) provide timely distribution of information on EMPs and credible associated threats to Federal, State, and local governments, critical infrastructure owners and operators, and other stakeholders;
(ii) coordinate response and recovery from the effects of space weather events on critical infrastructure and the broader community"	(ii) in coordination with the heads of any relevant SSAs [Sector-Specific Agencies], use the results of risk assessments to better understand and enhance resilience to the effects of EMPs across all critical infrastructure sectors, including coordinating the identification of national critical functions and the prioritization of associated critical infrastructure at greatest risk to the effects of EMPs;
	(iii) coordinate response to and recovery from the effects of EMPs on critical infrastructure, in coordination with the heads of appropriate SSAs;
	(iv) incorporate events that include EMPs as a factor in preparedness scenarios and exercises;
	(v) in coordination with the heads of relevant SSAs, conduct R&D to better understand and more effectively model the effects of EMPs on national critical functions and associated critical infrastructure—excluding Department of Defense systems and infrastructure—and develop technologies and guidelines to enhance these functions and better protect this infrastructure; and
	(vi) maintain survivable means to provide necessary emergency information to the public during and after EMPs"

Source: Executive Order 13744, "Coordinating Efforts to Prepare the Nation for Space Weather Events," 81 *Federal Register* 71574, October 18, 2016, and Executive Order 13865, "Coordinating National Resilience to Electromagnetic Pulses," 84 *Federal Register* 12043, March 29, 2019.

Both executive orders assign responsibility to DHS for early warning, response, and recovery functions related to space weather preparedness. However, E.O. 13865 also requires DHS to incorporate EMP scenarios into preparedness exercises, to conduct extensive R&D initiatives to better model EMP hazards and develop mitigation technologies, and to enhance critical infrastructure resilience against EMP hazards in coordination with other relevant federal agencies.

dated September 10, 2018; see "Update on LANL GMD Research Tasks," at https://www.osti.gov/biblio/1469512-update-lanl-gmd-research-tasks.

[84] For more information, contact Brian Humphreys, Analyst in Science and Technology Policy.

[85] See PPD-21, "Critical Infrastructure Security and Resilience."

The FY2020 NDAA includes several provisions directing the Secretary of Homeland Security to complete activities related to EMPs and GMDs. For example, Congress directed the Secretary, in coordination with other partners and under certain deadlines, to

- distribute EMP/GMD information to federal and nonfederal CI owners and operators and brief Congress on the effectiveness of the distribution;[86]
- conduct R&D to model the effects of EMPs/GMDs on CI, develop technologies to enhance CI resilience, and submit an action plan to address modeling shortfalls and technology development;[87]
- conduct a quadrennial EMP/GMD risk assessment, brief Congress on the results, and improve CI resilience using said results;[88]
- periodically report on technological options to improve CI resilience, identify gaps in available technologies, and develop and implement an integrated cross-sector plan to address the identified gaps;[89] and
- submit a report to Congress assessing the effects of EMPs/GMDs on communications CI and recommendations to operational plans to enhance response and recovery efforts after an EMP/GMD.[90]

The PROSWIFT Act does not contain specific critical infrastructure protection requirements or explicitly name DHS as a member of the interagency working group; however, DHS, and one of its agencies, the Federal Emergency Management Agency (FEMA), are both a part of the existing SWORM Interagency Working Group.[91]

The DHS Science and Technology Directorate, along with DHS operational components (the Cybersecurity and Infrastructure Security Agency and FEMA), manage relevant programs and activities. DHS utilizes an all-hazards risk management approach. Therefore, programs are generally not hazard-specific. Rather, DHS components leverage program capabilities as appropriate to support space weather resilience activities. High-level guidance for these programs and activities is provided by the DHS strategy "Protecting and Preparing the Homeland Against Threats of Electromagnetic Pulse and Geomagnetic Disturbances," published on October 9, 2018.[92]

Science and Technology Directorate (S&T)

S&T conducts R&D projects in partnership with federal agencies and the national laboratories, providing tools and analyses to help electric utilities better predict localized effects of space weather and enhance grid resilience.[93] For example, the Geomagnetic Field Calculator Tool,

[86] 6 U.S.C. 195f(d)(1)(A).

[87] 6 U.S.C. 195f(d)(1)(C).

[88] 6 U.S.C. 195f(d)(1)(E).

[89] 6 U.S.C. 195f(d)(2).

[90] P.L. 116-92, Sec. 1740 (g).

[91] SWORM, "About SWORM," at https://www.sworm.gov/about.htm.

[92] Department of Homeland Security, *Strategy for Protecting and Preparing the Homeland Against Threats of Electromagnetic Pulse and Geomagnetic Disturbances*, Washington, DC, October 9, 2018, https://www.dhs.gov/publication/protecting-and-preparing-homeland-against-threats-electromagnetic-pulse-and-geomagnetic.

[93] DHS Science and Technology Directorate, *Solar Storm Mitigation*, fact sheet, 2015, at https://www.dhs.gov/sites/default/files/publications/Solar%20Storm%20Mitigation-508_0.pdf.

developed for this purpose by S&T in partnership with NASA, is in the online testing phase.[94] Under the FY2020 NDAA, the Under Secretary for S&T, in coordination with federal and nonfederal partners, is required to develop and implement a pilot test to evaluate available engineering approaches to mitigate EMP/GMD effects on CI, and to brief Congress on its findings.[95] The pilot test was placed under contract with Los Alamos National Laboratory (LANL) and was scheduled for completion by July 2021 (**Table 1**).

Cybersecurity and Infrastructure Security Agency (CISA)

CISA administers public-private partnership programs that provide training, technical assistance, and on-site risk assessments to relevant private sector and federal partners. CISA, the Department of Energy, and interagency partners are producing technical guidance for electric utilities and other industry stakeholders on mitigation of electromagnetic hazards, which may include space weather. CISA provides long-term risk guidance and recommendations on EMP and other hazards to industry stakeholders through the National Risk Management Center.[96] CISA provides real-time space weather advisories to private sector owner-operators of vulnerable infrastructure on an as-needed basis.

Federal Emergency Management Agency (FEMA)[97]

FEMA develops operations plans and annexes that coordinate use of national resources to address consequences of space weather events. Recent operational documents include the Federal Operating Concept for Impending Space Weather Events (Space Weather Concept of Operations (CONOP)) and the Power Outage Incident Annex and Nuclear/Radiological Incident Annex to the Response and Recovery Federal Interagency Operational Plans. FEMA also periodically incorporates space weather scenarios into all-hazard education, training, and exercise programs. In 2017, FEMA conducted operational and tabletop exercises with federal and state partners. In 2018, FEMA conducted a space weather exercise for senior federal officials.[98]

Under the FY2020 NDAA, Congress directed the Administrator of FEMA, in coordination with other agencies and by certain deadlines, to

- coordinate the response to and recovery from the effects of EMPs/GMDs on CI;[99]
- incorporate EMPs/GMDs into preparedness scenarios and exercises;[100]
- conduct a national exercise to test the preparedness and response of the nation to the effects of EMPs/GMDs;[101] and

[94] NASA, "Geomagnetic Field Time Series Source," at https://kauai.ccmc.gsfc.nasa.gov/efieldtool/#about.

[95] P.L. 116-92, Sec. 1740(e).

[96] CISA, "National Risk Management," at https://www.cisa.gov/national-risk-management.

[97] Research for this section was contributed by CRS Analyst Elizabeth M. Webster, Analyst in Emergency Management and Disaster Recovery.

[98] Based on CRS email communication with Kyle Thomas, FEMA Congressional Affairs Specialist.

[99] 6 U.S.C. 195f(d)(1)(B).

[100] 6 U.S.C. 195f(d)(1)(B).

[101] 6 U.S.C. 195f(d)(1)(B).

- maintain a network of systems capable of providing emergency information to the public before, during, and after an EMP/GMD and brief Congress on such a system.[102]

These activities are in addition to the Secretary's required tasks. According to FEMA, it conducted a national exercise in December 2020 and continues work on other FY2020 NDAA requirements as part of ongoing programs (See **Table 1**).

Department of the Interior (DOI)[103]

The U.S. Geological Survey (USGS) is a scientific agency in DOI and aims to provide unbiased scientific information to describe and understand the geological processes of the Earth; minimize loss of life and property from natural disasters; and support the management of water, biological, energy, and mineral resources. [104] The Secretary of the Interior has delegated responsibilities from E.O. 13744 and E.O. 13865 to the USGS (**Table 7**).

Table 6. Responsibilities of the Secretary of the Interior Under E.O. 13744 and E.O. 13865

E.O. 13744	E.O. 13865
"The Secretary of the Interior shall support the research, development, deployment, and operation of capabilities that enhance the understanding of variations of the Earth's magnetic field associated with solar-terrestrial interactions."	"The Secretary of the Interior shall support the research, development, deployment, and operation of capabilities that enhance understanding of variations of Earth's magnetic field associated with EMPs."

Source: Executive Order 13744, "Coordinating Efforts to Prepare the Nation for Space Weather Events," 81 *Federal Register* 71573, October 18, 2016, and Executive Order 13865, "Coordinating National Resilience to Electromagnetic Pulses," 84 *Federal Register* 12043, March 29, 2019.

E.O. 13865 requires the USGS to enhance understanding of the variations of the Earth's magnetic field associated with all EMPs, human-made and space weather-related, whereas E.O. 13744 specifies only those resulting from solar-terrestrial interactions.

The USGS conducts space weather-related activities through the Geomagnetism program under the Natural Hazards Mission Area. The Geomagnetism program collects data about the Earth's dynamic magnetic field at 14 observatories.[105] The USGS provides these data and resulting products to federal agencies, oil drilling services companies, geophysical surveying companies, the electric-power industry, and several international agencies, among others.[106] For example, NOAA's Space Weather Prediction Center and the Air Force use USGS observatory data in geomagnetic warnings and forecasts. Congress appropriated $4.0 million to the Geomagnetism

[102] 6 U.S.C. 195f(d)(1)(D).

[103] For more information, contact Anna E. Normand, Analyst in Natural Resources Policy.

[104] For more information on the USGS, see CRS In Focus IF11850, *The U.S. Geological Survey (USGS): FY2022 Budget Request and Background*, by Anna E. Normand.

[105] U.S. Geological Survey, *Budget Justifications and Performance Information, Fiscal Year 2022*, p. 76, at https://prd-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/FY2022%20USGS%20Budget%20Justification%20%28Greenbook%29.pdf. Hereinafter USGS FY2022.

[106] The USGS magnetic observatory network is also part of the global INTERMAGNET network. For more information, see INTERMAGNET, "International Real-Time Magnetic Observatory Network," at http://www.intermagnet.org/index-eng.php.

program in FY2020 and $4.1 million in FY2021.[107] These appropriations included funding for the USGS to complete a national magnetotelluric survey initially started by NSF and NASA.[108] For FY2022, the Administration requested an increase of $1.5 million over FY2021 appropriations for the Geomagnetism program in order to begin adding the first of three planned new permanent observatory sites and to initiate the addition of roughly a dozen new low-cost variometer stations.[109]

Under the PROSWIFT Act, DOI is required to be a member of the interagency working group. The act also requires the Director of the USGS, in addition to other agency heads, to maintain and improve ground-based observations of the sun to meet data user needs and continue to provide space weather data through ground-based facilities.[110] The interagency working group is expected to develop formal mechanisms to (1) transmit space weather research findings, models, and capabilities from the USGS, and other agencies, to NOAA and DOD, and (2) communicate operational needs of NOAA and DOD space weather forecasters to the USGS and other agencies.[111] The FY2020 NDAA does not contain any specific provisions addressing the roles and responsibilities of DOI and the USGS in EMPs/GMDs.

Department of State (DOS)[112]

DOS is the lead foreign affairs agency in the executive branch. Among DOS's responsibilities is negotiating and promoting international norms and practices with respect to outer space. DOS maintains that these efforts contribute to its broader objective of promoting American prosperity through advancing bilateral relationships and leveraging international institutions.[113]

[107] Explanatory Statement submitted by Mrs. Lowey, Chairwoman of the House Committee on Appropriations, regarding the House amendment to the Senate amendment to H.R. 133, Consolidated Appropriations Act, 2021, *Congressional Record*, daily edition, vol. 166, part 218 (December 21, 2020), p. H8533.

[108] $1.7 million was allocated to the effort in FY2021. The initiative began in April 2020 through a cooperative agreement with Oregon State University, and the USGS estimates completion in 2024. According to the USGS, the survey will improve U.S. electric grid resilience, improve forecast models for geomagnetic storms, and aid in mineral resource assessments. The USGS further stated that collection of the data on a national scale is a basis for modeling the Earth's electric field, which can be used to assess the impact of electrical storms, and is responsive to priorities established in the National Space Weather Strategy and Executive Order 13865 for Coordinating National Resilience to Electromagnetic Pulses. The initiative includes scientists from NASA, NOAA, DOD, FERC, FEMA, and NSF. (U.S. Congress, House Committee on Appropriations, Department of the Interior, Environment, and Related Agencies Appropriations Bill, 2021, Report together with minority views to accompany H.R. 7612, 116th Cong., 2nd sess., July 14, 2020, H.Rept. 116-448, p. 46; and USGS FY2022, pp. 76-77).

[109] A variometer can measure ground-based monitoring of geomagnetic field variation for low frequencies that can be useful for many applications. Magnetic observatories are more expensive and labor-intensive to operate than variometer stations, but are needed for other applications. The USGS would conduct this expansion in coordination with the NOAA Space Weather Prediction Center and in response to the Space Weather Action Plan. The USGS states that this "expansion would enable delivery of accurate geoelectric hazard maps by reducing uncertainties that are primarily associated with the limited number of current observatories." USGS FY2022, pp. 76.

[110] 51 U.S.C. 60603(f) and (g).

[111] 51 U.S.C. 60604(d).

[112] For more information, contact Cory R. Gill, Analyst in Foreign Affairs.

[113] U.S. Department of State and U.S. Agency for International Development, *Joint Strategic Plan: FY2018–FY2022*, February 2018, p. 36, at https://www.state.gov/wp-content/uploads/2018/12/Joint-Strategic-Plan-FY-2018-2022.pdf.

Table 7. Responsibilities of the Secretary of State Under E.O. 13744 and E.O. 13865

E.O. 13744	E.O. 13865
"(h) The Secretary of State, in consultation with the heads of relevant agencies, shall carry out diplomatic and public diplomacy efforts to strengthen global capacity to respond to space weather events."	"(a) The Secretary of State shall: (i) lead the coordination of diplomatic efforts with United States allies and international partners regarding enhancing resilience to the effects of EMPs."

Source: Executive Order 13744, "Coordinating Efforts to Prepare the Nation for Space Weather Events," 81 *Federal Register* 71573, October 18, 2016, and Executive Order 13865, "Coordinating National Resilience to Electromagnetic Pulses," 84 *Federal Register* 12042, March 29, 2019.

E.O. 13744 requires the Secretary of State to lead implementation of U.S. diplomatic and public diplomacy efforts to enhance the international community's capacity to respond to space weather events. Similarly, E.O. 13865 directs the Secretary of State to lead U.S. engagement with allies and partners to enhance resilience to the effects of EMPs, which may include space weather (**Table 7**).[114] DOS's Bureau of Oceans and International Environmental and Scientific Affairs (OES) has traditionally been responsible for advancing U.S. diplomatic engagement on these matters. The FY2020 NDAA and PROSWIFT Act do not contain specific provisions addressing the roles and responsibilities of the State Department regarding space weather or EMPs/GMDs (DOS has been and continues to be a part of the existing SWORM Interagency Working Group).[115]

Congress established OES in Section 9 of the Department of State Appropriations Authorization Act of 1973 (P.L. 93-126).[116] OES is responsible for building international partnerships in multilateral fora to strengthen both U.S. and international resilience to extreme events, including those pertaining to space weather.[117] For example, OES's Office of Space Affairs leads U.S. delegations to the United Nations (U.N.) Committee on the Peaceful Uses of Outer Space (COPUOS).[118] In 2020, COPUOS's Legal Subcommittee noted the importance of increasing international cooperation in mitigating risks associated with adverse space weather to ensure increased global resilience against space weather effects.[119] COPUOS has also endorsed recent progress in this area, including the November 2019 launch of a new service under the auspices of the International Civil Aviation Organization to provide real-time information to the civil aviation sector regarding space weather that could potentially affect communications, navigation, and the

[114] E.O. 13865 further requires the Secretary of State to coordinate with the Department of Defense and other agencies to bolster nuclear nonproliferation and deterrence efforts with the intent of reducing the likelihood of an EMP attack against the United States or its allies and partners. However, a discussion of this tasking falls outside the scope of this report.

[115] SWORM, "About SWORM," at https://www.sworm.gov/about.htm.

[116] See 22 U.S.C. §2655a.

[117] U.S. Department of State, *Bureau of Oceans and International Environmental and Scientific Affairs*, Functional Bureau Strategy, August 31, 2018, p. 8, at https://www.state.gov/wp-content/uploads/2019/01/FBS-OES_UNCLASS-508.pdf.

[118] U.S. Department of State, Office of Space Affairs, "About Us," at https://www.state.gov/about-us-office-of-space-affairs/.

[119] United Nations, Committee on the Peaceful Uses of Outer Space, Legal Subcommittee, "Revised Draft 'Space2030' Agenda and Implementation Plan," 59th Session, Vienna, March 23-April 3, 2020, p. 6, at https://www.unoosa.org/res/oosadoc/data/documents/2020/aac_105c_2l/aac_105c_2l_316_0_html/AC105_C2_L316E.pdf.

health of passengers and crew.[120] NOAA's aforementioned Space Weather Prediction Center is among the entities participating in this service.[121]

In recent years, Congress has conducted oversight of U.S. participation in COPUOS through annual Department of State, Foreign Operations, and Related Programs (SFOPS) appropriations laws. The FY2020 SFOPS law required the Secretary of State to submit a report to Congress describing U.S. efforts to support COPUOS.[122] The State Department submitted this report to Congress in May 2020, which endorsed the 21 guidelines for the Long-Term Sustainability of Outer Space Activities (LTS Guidelines) that COPUOS adopted in June 2019. Among other priorities, these guidelines call on the international community to share operational space weather data and forecasts and, separately, identify and fill gaps in research and operational models and forecasting tools needed to meet the needs of providers and users of space weather information services.[123]

National Aeronautics and Space Administration (NASA)[124]

Under 51 U.S.C. §20301, NASA is responsible for scientific research on the "Sun-Earth connection through the development and operation of research satellites and other means."[125] While E.O. 13865 does not address NASA, E.O. 13744 further directs NASA to

> (i) implement and support a national research program to understand the Sun and its interactions with Earth and the solar system to advance space weather modeling and prediction capabilities applicable to space weather forecasting;
>
> (ii) develop and operate space-weather-related research missions, instrument capabilities, and models; and
>
> (iii) support the transition of space weather models and technology from research to operations and from operations to research.

The Heliophysics Division of NASA's Science Mission Directorate supports fundamental research on the sun, some of which is important for space weather prediction, but most of which is less directly applicable.[126] Congress appropriated $751 million to the Heliophysics Division in

[120] United Nations, Committee on the Peaceful Uses of Outer Space, Scientific and Technical Subcommittee, "Progress report on the work of the Expert Group on Space Weather at the 57th session of the Subcommittee," 57th Session, Vienna, February 3-February 14, 2020, p. 3, at https://www.unoosa.org/res/oosadoc/data/documents/2020/aac_105c_12020crp/aac_105c_12020crp_13_0_html/AC105_C1_2020_CRP13E.pdf; and United Nations, Committee on the Peaceful Uses of Outer Space, Scientific and Technical Subcommittee, "Draft Report," 57th Session, Vienna, February 3-February 14, 2020, p. 5 at https://www.unoosa.org/res/oosadoc/data/documents/2020/aac_105c_1l/aac_105c_1l_385_0_html/AC105_C1_L285E.pdf.

[121] International Civil Aviation Organization, "New Global Aviation Space Weather Network Launched," November 19, 2019, at https://www.icao.int/Newsroom/Pages/New-global-aviation-space-weather-network-launched.aspx.

[122] To read the reporting requirement, see U.S. Congress, Senate Committee on Appropriations, "Department of State, Foreign Operations, and Related Programs Appropriations Bill, 2020," report to accompany S. 2583, 116th Cong., 1st sess., S.Rept. 116-126, September 26, 2019 (Washington, DC: GPO, 2019), pp. 38-39. This reporting requirement was included in the final appropriations law pursuant to Section 7019(e) of P.L. 116-94.

[123] United Nations, Committee on the Peaceful Uses of Outer Space, "Report of the Committee on the Peaceful Uses of Outer Space," 62nd Session, June 12-21, 2019, pp. 62-63 at https://www.unoosa.org/res/oosadoc/data/documents/2019/a/a7420_0_html/V1906077.pdf.

[124] For more information, contact Daniel Morgan, Specialist in Science and Technology Policy.

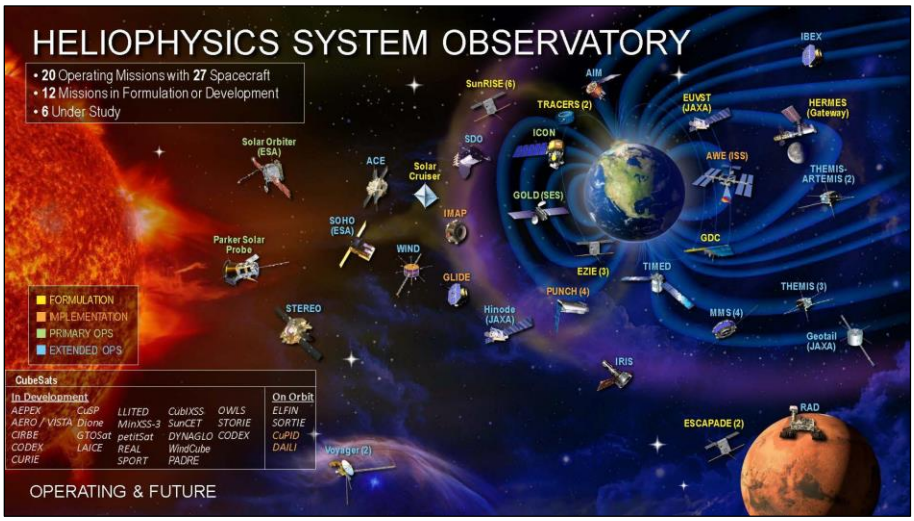
[125] 51 U.S.C. §20301(a)(3)(B).

[126] For more information, see https://science.nasa.gov/heliophysics.

FY2021. CBO estimates that NASA allocated $264 million to space weather activities in FY2019.[127] The Heliophysics Division funds intramural and extramural research and operates a fleet of research spacecraft in Earth orbit and beyond. These study the sun, the solar wind, and their interaction with Earth and the rest of the Solar System (see **Figure 3**). NASA provides research data and modeling results to NOAA for operational use by the Space Weather Prediction Center when it observes a space weather event or disturbance.

In addition to its research activities, NASA has unique operational concerns regarding space weather. First, while multiple agencies and the private sector operate satellites in Earth orbit, above the protection provided by Earth's atmosphere, NASA also has spacecraft in orbits far beyond Earth for planetary exploration and other missions. Earth's magnetic field provides significant protection against space weather for Earth-orbiting satellites, but spacecraft outside Earth's magnetosphere do not benefit from this protection and so have additional requirements for radiation shielding and other countermeasures. Second, NASA is the only U.S. agency with astronauts in space, so it has unique human safety concerns. Human safety concerns are particularly significant for planned future missions to the Moon and other destinations that are beyond Earth's protective magnetosphere.

Figure 3. NASA Heliophysics Satellites as of January 2022



Source: NASA, "NASA Heliophysics," at https://science.nasa.gov/heliophysics

The PROSWIFT Act contains several relevant requirements for NASA. NASA is required to be a part of the interagency working group, and, together with NOAA, is required to enter into interagency agreements to develop "space weather spacecraft, instruments, and technologies."[128] NASA and NOAA are also required to enter into an agreement with NASEM to review the OSTP-developed space weather observation strategy and transmit NASEM findings to Congress.[129] NASA must maintain operation of the Solar and Heliospheric Observatory Large Angle Spectroscopic Coronagraph (SOHO/LASCO), a spacecraft orbiting the sun that provides imagery of coronal mass ejections, for "as long as the satellite continues to deliver quality

[127] Email communication between CRS and Robert Reese, Congressional Budget Office, on October 1, 2019.

[128] 51 U.S.C. 60601(c).

[129] 51 U.S.C. 60602(c).

observations" and must prioritize the reception of SOHO/LASCO data.[130] The act also directs NASA, among other agencies, to continue to carry out basic research on heliophysics, geospace science, and space weather; support competitive research, modeling, and monitoring proposals; and pursue multidisciplinary research to further the understanding of solar physics, space physics, and space weather.[131] NASA is also required to make space weather-related data obtained for research available to space weather forecasters, and support model development and applications for space weather forecasting.[132] Finally, NASA "should" implement missions that meet the science objectives identified in NASEM decadal surveys.[133] The FY2020 NDAA does not contain specific provisions addressing the roles and responsibilities of NASA regarding EMPs/GMDs.

National Science Foundation (NSF)[134]

Congress established the NSF to "promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes."[135] E.O. 13744 further directs NSF to "support fundamental research linked to societal needs for space weather information through investments and partnerships, as appropriate." NSF supports space weather research in two directorates: (1) the Geosciences Directorate (GEO), including through the Division of Atmospheric and Geospace Sciences (AGS) and the GEO Office of Polar Programs (OPP); and (2) the Mathematical and Physical Sciences (MPS) Directorate, through the MPS Division of Astronomical Sciences (AST).[136] E.O. 13865 does not address NSF.

NSF reports that FY2019 space weather funding totaled approximately $90 million, including about $65 million provided by GEO and about $25 million provided by AST.[137] CBO estimated that NSF allocated $22 million to space weather activities in FY2019.[138] FY2020 space weather funding totaled approximately $109 million, including about $77 million provided by GEO and about $32 million provided by AST.[139] NSF primarily provides grants to research institutions to

[130] 51 U.S.C. 60603(b)(1).

[131] 51 U.S.C. 60604(a) and (b)(3).

[132] 51 U.S.C. 60605(a).

[133] 51 U.S.C. 60604(c). As mandated by 51 U.S.C. 20305, the NASEM conducts regular decadal surveys of each of NASA's science divisions, recommending scientific priorities for the coming 10 years. These reports are an influential source of guidance for NASA's program planning. See NASA, "Most Recent Decadal Surveys," at https://science.nasa.gov/about-us/science-strategy/decadal-surveys. The most recent decadal survey of solar and space physics was published in 2013. The next is planned for 2024 (see NASA, "Heliophysics 2024 Decadal Survey," at https://science.nasa.gov/heliophysics/resources/2024_decadal_survey).

[134] For more information, contact Laurie A. Harris, Analyst in Science and Technology Policy.

[135] National Science Foundation (NSF) Act of 1950, May 10, 1950, ch. 171, 64 Stat. 149.

[136] In NSF's organizational structure, directorates contain multiple divisions and offices; see https://www.nsf.gov/staff/orglist.jsp.

[137] Email communication between CRS and NSF, February 2, 2021.

[138] Email communication between CRS and Robert Reese, Congressional Budget Office, October 1, 2019. According to NSF, "the CBO FY2019 Estimate comes from the Federal Weather Enterprise Budget and Coordination Report and corresponds to the National Space Weather Strategy and National Space Weather Action Plan. [The NSF estimate] provided to CRS was in response to a data call for 'NSF support [of] space weather activities.' This request was based off of a broader definition to include activities in support of space weather versus those more narrowly defined as related to the National Space Weather Strategy and National Space Weather Action Plan. The broader definition of support activities include[s] research on solar surface, as well as a larger set of atmospheric and geospace sciences research not included in the Federal Weather report." Email communication between CRS and NSF on October 18, 2019.

[139] Email communication between CRS and NSF, February 2, 2021.

conduct scientific studies, including universities and private entities that focus on fundamental research questions related to space weather and its impacts. The AGS division supports both basic sciences research and observational and cyber-infrastructure facilities—including the National Center for Atmospheric Research's High Altitude Observatory (NCAR/HAO)—to improve understanding of the dynamics of the sun, Earth's atmosphere, and near-Earth space environment, and how the sun interacts with Earth's atmosphere. OPP support includes the Antarctic and Astrophysics Geospace program and the IceCube Neutrino Observatory (jointly funded with the MPS Division of Physics). In the MPS ATS division—the federal steward for ground-based astronomy in the United States—observations focus mainly on the sun, and activities include management of the National Solar Observatory (NSO) Integrated Synoptic Program and the Daniel K. Inouye Solar Telescope (DKIST). According to NSF, DKIST will play an important role in enhancing the fundamental understanding of space weather and its drivers. In addition, NSF supports the development of numerical models of the space weather chain, including the sun, solar wind, and geospace.[140] Additionally, FY2020 funding for the MPS division included contributions to the new NSF-NASA joint program on Next Generation Software for Data-driven Models of Space Weather with Qualified Uncertainties (SWQU).[141]

E.O. 13744 further directs NSF, in collaboration with other federal agencies, to identify mechanisms for advancing space weather observations, models, and predictions, and for sustaining and transitioning appropriate capabilities from research to operations and from operations to research. As noted in the agency's March 2018 announcement regarding space weather operations-to-research proposals, NSF's primary role in space weather readiness efforts is support for basic research that advances fundamental understanding of space weather and related processes, including "the generation of solar storms, their propagation through the interplanetary medium, and their impact on the near-Earth space environment."[142]

Under the PROSWIFT Act, NSF is required to be a part of the interagency working group and help to fulfill the working group's responsibilities.[143] The act requires the Director of NSF, among other agency heads, to maintain and improve ground-based observations of the sun to meet data user needs, and continue to provide space weather data through ground-based facilities.[144] NSF is required to make SOHO/LASCO data publicly available, develop data models for experimental purposes, and support transitions from experimental models to operations.[145] The Director of NSF, among other agency heads, is also tasked with (1) continuing to carry out basic research on heliophysics, geospace science, and space weather; (2) supporting competitive space weather research, modeling, and monitoring proposals;[146] and (3) pursuing multidisciplinary research in subjects that further the understanding of solar physics, space physics, and space weather.[147] Finally, NSF and NASA are to continue to make space weather-related data obtained from research available to space weather forecasters and to support model development and

[140] Email communications between CRS and NSF, August 12, 2019; and NSF, *FY2021 Budget Request to Congress*, February 10, 2020.

[141] Email communication between CRS and NSF on February 2, 2021.

[142] National Science Foundation, "Dear Colleague Letter: Space Weather Operations-to-Research Proposals," NSF 18-052, March 9, 2018, at https://www.nsf.gov/pubs/2018/nsf18052/nsf18052.jsp.

[143] 51 U.S.C. 60601(c).

[144] 51 U.S.C. 60603(f).

[145] 51 U.S.C. 60603(h).

[146] 51 U.S.C. 60604(a).

[147] 51 U.S.C. 60604(b)(3).

applications to space weather forecasting.[148] The FY2020 NDAA does not contain specific provisions addressing the roles and responsibilities of NSF regarding EMPs/GMDs.

Federal Agency Spending on Space Weather Activities

A comprehensive account of total federal agency spending on space weather-related activities is not available. In a cost estimate for the Space Weather Research and Forecasting Act (S. 881 in the 116th Congress), CBO estimated that the federal agencies in the National Space Weather Program and the Space Weather Operations, Research, and Mitigation Working Group "allocated a combined total of nearly $350 million to activities related to space weather" in FY2019.[149] CBO estimated that NASA allocated the majority ($264 million) of the $350 million total.[150] Total federal agency allocations towards space weather activities may differ from year to year. For example, CBO estimated federal agencies that were a part of the National Space Weather Program "spent a total of $160 million" in FY2016 on activities related to space weather.[151] More recent spending estimates are not available.

The Consolidated Appropriations Act, 2022 (P.L. 117-103) continues support for maintenance and modernization of satellites used for space-weather forecasting. IIJA authorizes over $200 million in additional appropriations that support certain infrastructure resilience programs and activities, which—depending on implementation—may include some space weather projects (see "Legislation in the 117th Congress").

Additional Considerations

Members may continue to be interested in providing oversight of existing space weather responsibilities, including the multiple space weather-related provisions enacted in the 116th and 117th Congresses described above. Congress may also modify existing space weather policy guidance if needed. For example, E.O. 13865 applies to both space weather and human-made electromagnetic hazards (such as a nuclear attack) and refers to both types of hazard as electromagnetic pulse (EMP). This may create ambiguity in cases where a given provision could apply either to manmade human-made or natural electromagnetic hazards.[152] That E.O. 13865 does not formally supersede E.O. 13744 (which refers solely to space weather) may create further ambiguity in cases where policies of different Administrations are not in direct alignment, or else reflect differing priorities.

[148] 51 U.S.C. 60605(a).

[149] Congressional Budget Office (CBO), *Cost Estimate, At a Glance, S. 881, Space Weather Research and Forecasting Act*, May 31, 2019, at https://www.cbo.gov/system/files/2019-05/s881.pdf.

[150] Email communication between CRS and Robert Reese, Congressional Budget Office, on October 10, 2019.

[151] CBO, *Cost Estimate*, S. 141, *Space Weather Research and Forecasting Act*, February 24, 2017, at https://www.cbo.gov/sites/default/files/115th-congress-2017-2018/costestimate/s141.pdf.

[152] For example, E.O. 13865 directs the Secretary of Homeland Security to "incorporate events that include EMPs as a factor in preparedness scenarios and exercises," without specifying whether a space weather event or nuclear attack scenario should be exercised, or which should be prioritized. Federal agencies typically regard—and refer to—human-made EMP and naturally occurring GMDs as related, but distinct phenomena.

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