Congressional Research Service
Informing the legislative debate since 1914

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

Updated January 6, 2020

Congressional Research Service
https://crsreports.congress.gov
R46049

CRS REPORT
Prepared for Members and
Committees of Congress

Congressional Research Service
Informing the legislative debate since 1914

SUMMARY

R46049

January 6, 2020

Eva Lipiec
Analyst in Natural Resources Policy

Brian E. Humphreys
Analyst in Science and Technology Policy

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.

In 2010, Congress 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 (P.L. 111-267). 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 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 and the National Weather Service are the primary civilian agencies responsible for space weather forecasting. The National Laboratories (administered by the Department of Energy), the National Aeronautics and Space Administration (NASA), and the National Science Foundation support forecasting activities with scientific research. Likewise, the U.S. Geological Survey provides data on the 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 supports military operations with its own space weather forecasting capabilities, sharing expertise and data with other federal agencies as appropriate.

The Congressional Budget Office estimated that federal agencies participating in the SWORM 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 116th Congress is considering space weather-related legislation. House and Senate versions of FY2020 National Defense Authorization Act (NDAA) legislation (H.R. 2500 and S. 1790) would require the National Guard to report on available resources to respond to EMP events. The House version would dissolve the Congressional EMP Commission. The Senate version would pass certain E.O. 13865 requirements into law. In addition to provisions of the FY2020 NDAA, some Members of Congress have introduced the Space Weather Research and Forecasting Act (S. 881), which would define certain federal agency roles and responsibilities, among other provisions. Versions of this bill were also introduced in the 114th and 115th Congresses.

Contents

Introduction 1
Federal Interagency Activities 2
Select Department and Agency Roles and Responsibilities 6
Department of Commerce 6
Department of Defense (DOD) 7
Air Force 9
Army 9
Navy 9
Department of Energy (DOE) 9
Office of Cyber Security, Energy Security, and Emergency Response (CESER) 10
Federal Energy Regulatory Commission (FERC) 11
North American Electric Reliability Corporation (NERC) 11
National Laboratories 12
Department of Homeland Security (DHS) 12
Science and Technology Directorate (S&T) 13
Cybersecurity and Infrastructure Security Agency (CISA) 13
Federal Emergency Management Agency (FEMA) 13
Department of the Interior (DOI) 14
Department of State (DOS) 14
Bureau of Oceans and International Environmental and Scientific Affairs (OES) 15
National Aeronautics and Space Administration (NASA) 16
National Science Foundation (NSF) 17
Federal Agency Spending on Space Weather Activities 18
Legislation in the 116th Congress 19
The National Defense Authorization Act for Fiscal Year 2020 (P.L. 116-92) 19
The Space Weather Research and Forecasting Act (S. 881) and Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act (H.R. 5260) 20

Figures

Figure 1. Examples of Potential Effects of Space Weather 2
Figure 2. 2019 National Space Weather Strategy and Action Plan Objectives by Agency 5
Figure 3. NASA Heliophysics Satellites as of July 2019 17

Tables

Table 1. Responsibilities of the Secretary of Commerce Under E.O. 13744 and E.O. 13865 7
Table 2. Responsibilities of the Secretary of Defense Under E.O. 13744 and E.O. 13865 8
Table 3. Responsibilities of the Secretary of Energy Under E.O. 13744 and E.O. 13865 10
Table 4. Responsibilities of the Secretary of Homeland Security Under E.O. 13744 and E.O. 13865 12

Table 5. Responsibilities of the Secretary of the Interior Under E.O. 13744 and E.O. 13865 14
Table 6. Responsibilities of the Secretary of State Under E.O. 13744 and E.O. 13865 15
Table 7. Summary of Requirements in Section 1740 of the 2020 NDAA 19

Contacts

Author Information 20

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 highly-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 CI systems and assets that are vulnerable to geomagnetically induced current, electromagnetic interference, or radiation exposure (see **Figure 1**).[3]

Several notable events illustrate space weather hazards, and how their potential impact 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]

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.

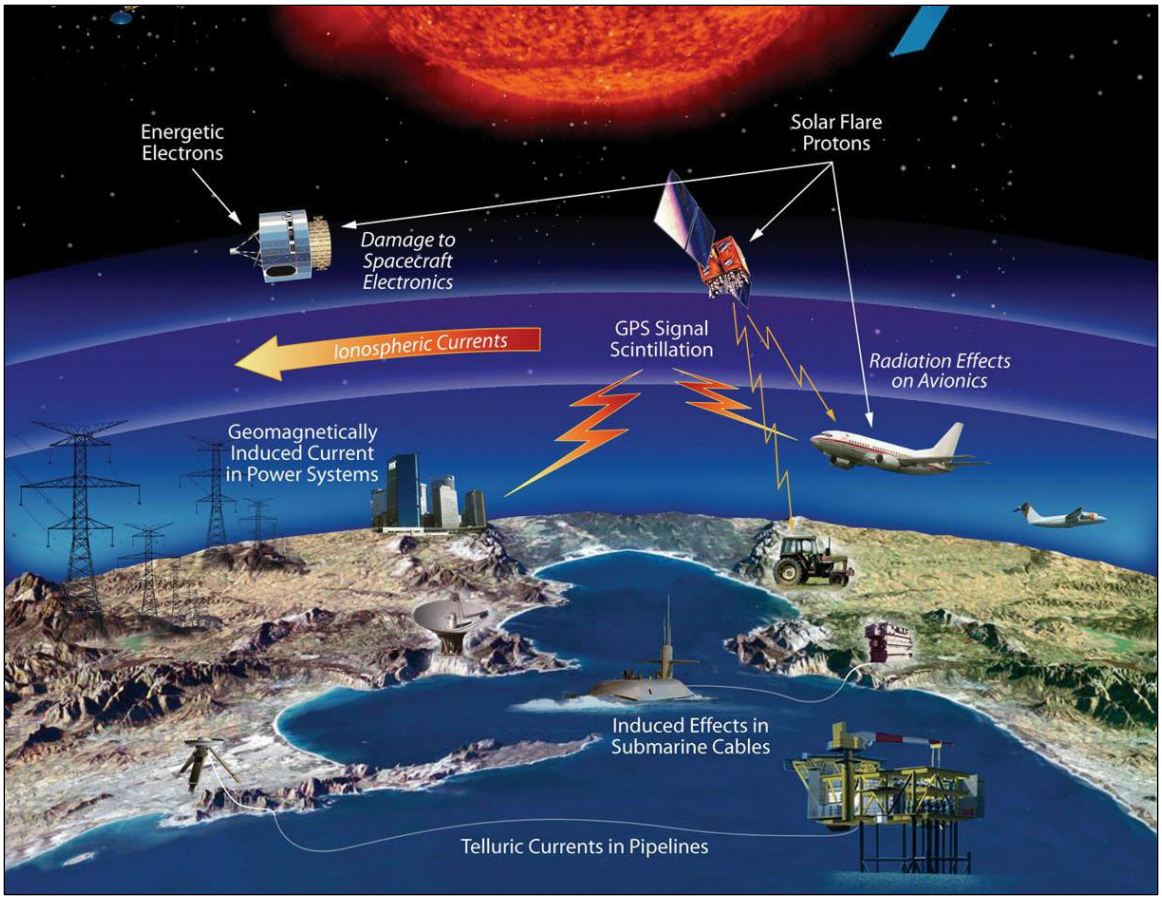
[1] National Aeronautics and Space Administration (NASA), "Space Weather," at https://www.nasa.gov/mission_pages/rbsp/science/rbsp-spaceweather.html.

[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.

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

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.[5] The program was directed by the NSWP Council that included representatives from interested federal agencies. The NWSP Council coordinated federal space weather strategy development between 1995 and 2015 in partnership with federal agencies, industry, and the academic community.[6]

[5] 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.

[6] The NSWP Council was comprised 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.

In 2010, 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.[7] This marked the beginning of a period during which the White House assumed leadership of federal space weather policy. 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.[8] The NSWP Council was deactivated the following year, when SWORM published a national space weather preparedness strategy, titled the "National Space Weather Strategy" (the 2015 Plan).[9]

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 Plan.[10] The SWORM Working Group released an updated national space weather strategy in 2019, titled "The National Space Weather Strategy and Action Plan" (the 2019 Plan).[11] 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.[12]

1995–2019 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.
2014	NSTC establishes the Space Weather Operations, Research, and Mitigation (SWORM) Working Group.
2015	The SWORM Working Group publishes the "National Space Weather Strategy."
	The NSWP Council is deactivated.[13]
2016	President Obama signs Executive Order (E.O.) 13744, "Coordinating Efforts to Prepare the Nation for Space Weather Events."
2019	The SWORM Working Group releases updated national space weather strategy.
	President Trump signs (E.O.) 13865, "Coordinating National Resilience to Electromagnetic Pulses."

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 that of the previous

[7] P.L. 111-267; 42 U.S.C. §18388.

[8] SWORM is referred to as a working group or task force, depending on the document. See Michael F. Bonadonna 2016 and National Science and Technology Council, *National Space Weather Strategy*, Washington, DC, October 2015. The SWORM Working Group is comprised of representatives from 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.

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

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

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

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

[13] Michael F. Bonadonna 2016.

Administration set forth in the 2015 Plan and E.O 13744.[14] 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 directs relevant federal agencies to identify regulatory and cost-recovery mechanisms that the government may use to compel private-sector investments in resilience.[15] This approach differs from most other federal infrastructure resilience initiatives, which generally rely upon voluntary industry adoption of resilience measures.[16]

E.O. 13865 applies both to space weather and manmade 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 or natural electromagnetic hazards. 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.[17] The fact 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 the previous and current Administrations are not in direct alignment, or else reflect differing priorities. Federal agencies typically regard—and refer to—manmade EMP and naturally-occurring GMDs as related, but distinct phenomena.

[14] 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.

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

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

[17] E.O. 13865, Section 5f(iv).

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

Objectives	DHS	DOC	DOD	DOE	DOI	DOS	DOT	EPA	FCC	HHS	NASA	NRC	NSF	Treas.
Enhance the protection of national security, homeland security, and commercial assets and operations against the effects of space weather.	✕	✕	✕	✕	✕	✕	✕	✕	✕	✕	✕	✕	✕	✕
Develop and disseminate accurate and timely space weather characterization and forecasts.	✕	✕	✕	✕	✕	✕		✕			✕		✕	✕
Establish plans and procedures for responding to and recovering from space weather events.	✕	✕	✕	✕	✕	✕	✕	✕		✕	✕	✕		✕

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.

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. Federal agency roles and responsibilities fall into four 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 only includes entities that relevant executive orders or strategies have designated as the federal lead for a specific objective or requirement. This does not include 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.

Each sub-section includes a summary of the department or agency mission and the relevant authorities under which it operates. 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. Provisions applicable only to manmade EMP threats, such as high-altitude nuclear detonations, are excluded.

The 2019 Plan is referenced in cases where the executive orders do not provide specific or complete guidance to given federal entities. Departments and agencies are ordered alphabetically for ease of reference.

Department of Commerce[18]

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."[19] 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 1**).

[18] Eva Lipiec, CRS Analyst in Natural Resources Policy, was the lead author of this section.

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

Table 1. 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 partner 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.

NOAA's space weather work falls primarily under two line offices: National Weather Service (NWS) and National Environmental Satellite, Data, and Information Service (NESDIS).[20] 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.[21] 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.[22] NESDIS maintains NOAA's space weather data through the National Centers for Environmental Information.[23] 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.[24]

Department of Defense (DOD)[25]

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 2**).

[20] NOAA, "Budget Estimates, Fiscal Year 2020," at https://www.corporateservices.noaa.gov/nbo/fy20_bluebook/NOAA-FY20-Congressional-Justification.pdf.

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

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

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

[24] 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.

[25] Stephen McCall, CRS Analyst in Military Space, Missile Defense, and Defense Innovation, was the lead author of this section.

Table 2. 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 FY2018 National Defense Authorization Act (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.

Air Force

The U.S. Air Force is the lead for all DOD and Intelligence Community (IC) space weather information.[26] Air Force weather personnel provide space environmental information, products, and services required to support DOD operations as required.[27] Air Force space weather operations and capabilities 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.[28]

The 557th Weather Wing, located at Offutt Air Force Base, Nebraska, conducts most of DOD's space weather-related activities. 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.[29]

Army

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

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.[30] 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.[31]

Department of Energy (DOE)[32]

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.[33]

---

[26] 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.

[27] 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.

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

[29] 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.

[30] 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.

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

[32] Heather L. Greenley, CRS Analyst in Energy Policy, was the lead author of this section.

[33] The White House, "Critical Infrastructure Security and Resilience," Presidential Policy Directive 21, February 12,

Table 3. 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 3**).

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) (under the Office of Electricity), and 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, a new office created from the Office of Electricity Delivery and Energy Reliability (OE). CESER has two main divisions: Infrastructure Security and Energy Response (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."[34]

The 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.[35] 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

2013. P.L. 114-94 codified the designation of DOE as the sector-specific agency for the energy sector (6 U.S.C. §121 note).

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

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

documents focus specifically on human-made nuclear threats and categorize GMDs separately from EMPs.[36] 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."[37]

Federal Energy Regulatory Commission (FERC)

FERC is an independent government agency officially organized as part of DOE.[38] The Energy Policy Act of 2005 (EPAct05; P.L. 109-58) authorized FERC to oversee the reliability of the bulk-power system.[39] 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 reliability standards subject to FERC oversight.[40] 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).[41] 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.[42] 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 the public and private electric utilities to develop and enforce FERC-approved standards.[43] 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.[44]

---

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

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

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

[39] 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.

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

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

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

[43] 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.

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

National Laboratories

DOE oversees 17 national laboratories that advance science and technology research and development to support DOE's mission. The Los Alamos National Laboratory is currently working on a study of EMP and GMD physical characteristics and effects on critical infrastructure, to be carried out in four phases.[45]

Department of Homeland Security (DHS)[46]

Under Presidential Policy Directive 21 (PPD-21), DHS is the lead U.S. agency for critical infrastructure protection and disaster preparedness.[47] E.O. 13744 and E.O. 13865 assign several roles and responsibilities to DHS specific to space weather and EMPs (**Table 4**).

Table 4. 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"

[45] 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. An update on research tasks indicates that LANL GMD research was still active as of September 10, 2018. See "Update on LANL GMD Research Tasks," at https://www.osti.gov/biblio/1469512-update-lanl-gmd-research-tasks.

[46] Brian Humphreys, CRS Analyst in Science and Technology Policy, was the lead author of this section.

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

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.

Relevant programs and activities are managed by the Department's Science and Technology Directorate, as well as two DHS operational components: the Cybersecurity and Infrastructure Security Agency, and the Federal Emergency Management Agency. DHS utilizes an all-hazards risk management approach. Therefore, programs are generally not hazard-specific, but rather may be used to support space weather resilience activities as needed.

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 utilities better predict localized effects of space weather and enhance grid resilience.[48] For example, the Geomagnetic Field Calculator Tool, developed for this purpose by S&T in partnership with NASA, is in the online testing phase.[49]

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.[50] 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)[51]

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.

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

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

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

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

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.[52]

Department of the Interior (DOI)[53]

The U.S. Geological Survey (USGS) is DOI's lead scientific agency and "provides research and integrated assessments of natural resources; supports the stewardship of public lands and waters; and delivers natural hazard science to protect public safety, health, and American economic prosperity."[54] The Secretary of the Interior has delegated responsibilities from E.O. 13744 and E.O. 13865 to USGS (**Table 5**).

Table 5. 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 USGS to enhance understanding of the variations of the Earth's magnetic field associated with all EMPs, manmade and space weather-related, whereas E.O. 13744 specifies only those resulting from solar-terrestrial interactions.

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 11 observatories. 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.[55] For example, NOAA's Space Weather Prediction Center and the Air Force use USGS observatory data in geomagnetic warnings and forecasts. Congress appropriated $1.9 million to the Geomagnetism program in FY2019.

Department of State (DOS)[56]

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

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

[53] Anna E. Normand, CRS Analyst in Natural Resources Policy, was the lead author of this section.

[54] U.S. Geological Survey, *Budget Justifications and Performance Information, Fiscal Year 2020*, p. 1, at https://www.doi.gov/sites/doi.gov/files/uploads/fy2020_usgs_budget_justification.pdf.

[55] 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.

[56] Cory R. Gill, CRS Analyst in Foreign Affairs, was the lead author of this section.

maintains that these efforts contribute to its broader objective of promoting American prosperity through advancing bilateral relationships and leveraging international institutions.[57]

Table 6. 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 (see **Table 6**).[58] DOS's Bureau of Oceans and International Environmental and Scientific Affairs has traditionally been responsible for advancing U.S. diplomatic engagement on these matters.

Bureau of Oceans and International Environmental and Scientific Affairs (OES)

Congress established the Bureau of Oceans and International Environmental and Scientific Affairs in Section 9 of the Department of State Appropriations Authorization Act of 1973 (P.L. 93-126).[59] 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.[60] For example, OES's Office of Space and Advanced Technology leads U.S. delegations to the United Nations (U.N.) Committee on the Peaceful Uses of Outer Space (COPUOS). In 2017, OES participated in a workshop co-hosted by the United Nations and NASA on the International Space Weather Initiative (ISWI). The ISWI was first launched in 2009 to advance space weather science through deploying instruments to collect relevant space weather data, analyzing and interpreting the data obtained from those instruments, and communicating the results of that analysis to the public.[61] The United States and 43 other U.N. member states that participated in this workshop found that strengthening the international framework for space weather services could be accomplished through several means. These included further improving

[57] 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.

[58] 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, this tasking falls outside the scope of this report.

[59] See 22 U.S.C. §2655a.

[60] 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.

[61] United Nations General Assembly, Committee on the Peaceful Uses of Outer Space, *Report of the United Nations/United States of America Workshop on the International Space Weather Initiative: The Decade After the International Heliophysical Year 2007*, September 11, 2017, at https://cms.unov.org/dcpms2/api/finaldocuments?Language=en&Symbol=A/AC.105/1160, p. 2.

ground and space-based space weather observation infrastructure, sharing best practices for space weather risk assessment and mitigation, increasing coordination on space weather forecasting services, and developing space weather mitigation plans for integration into broader contingency planning for disaster management.[62] These action items are consistent with DOS's responsibilities to contribute to the realization of the 2019 Plan's three key objectives.[63] Efforts by COPUOS to make progress in these and other focus areas are ongoing.[64]

National Aeronautics and Space Administration (NASA)[65]

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."[66] 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.[67] Congress appropriated $720 million to the Heliophysics Division in FY2019. CBO estimates that NASA allocated $264 million to space weather activities in FY2019.[68] The Heliophysics Division funds intramural and extramural research and operates a fleet of research spacecraft in Earth orbit and beyond to study the sun, the solar wind, and their interaction with Earth and the rest of the Solar System (see **Figure 3**). When a space weather event or disturbance is observed, NASA also provides research data and modeling results to NOAA for operational use by the Space Weather Prediction Center.

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 human astronauts in space, so it has unique human safety concerns. Human safety concerns are

[62] Ibid, pp. 4-6.

[63] National Science and Technology Council, *National Space Weather Strategy and Action Plan*, March 2019, p. 4.

[64] For example, see United Nations General Assembly, Committee on the Peaceful Uses of Outer Space, *Report of the Scientific and Technical Subcommittee on its fifty-sixth session, held in Vienna from 11 to 22 February 2019*, February 28, 2019, at https://cms.unov.org/dcpms2/api/finaldocuments?Language=en&Symbol=A/AC.105/1202.

[65] Dan Morgan, CRS Specialist in Science and Technology Policy, was the lead author of this section.

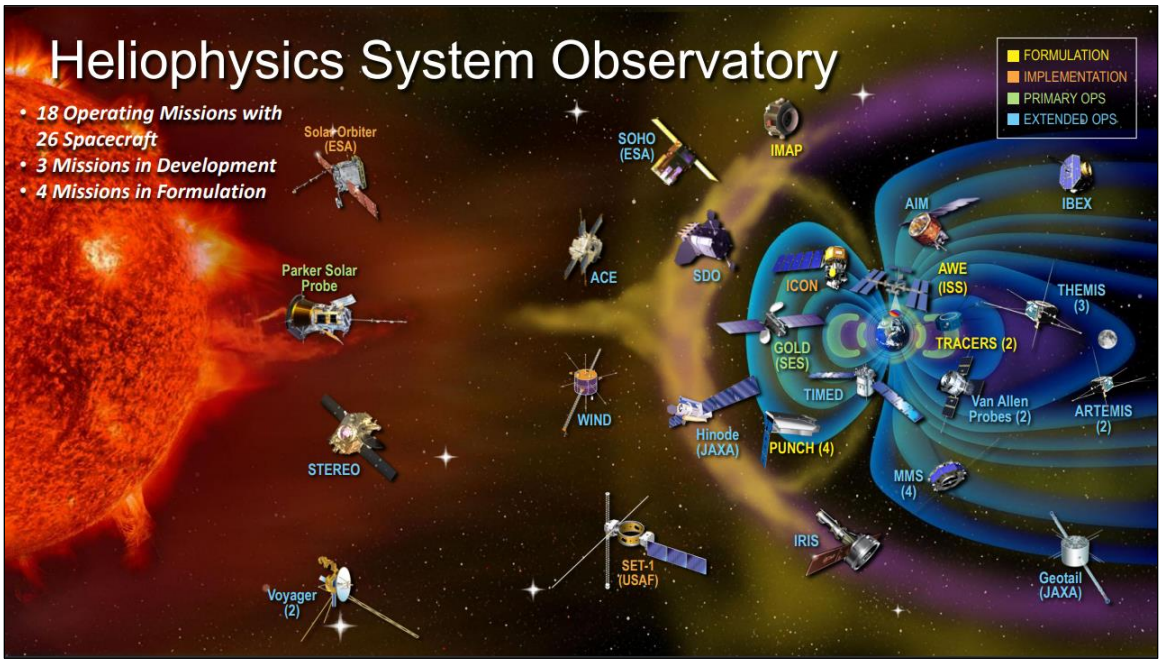
[66] 51 U.S.C. §20301(a)(3)(B).

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

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

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 July 2019



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

National Science Foundation (NSF)[69]

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."[70] 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, including through the Atmospheric and Geospace Sciences division (AGS) and the Office of Polar Programs (OPP), and (2) the Mathematical and Physical Sciences (MPS) Directorate, through the Astronomical Sciences division (AST). E.O. 13865 does not address NSF.

NSF reports that FY2018 space weather funding totaled approximately $105 million, including about $45 million for AST.[71] CBO estimates that NSF allocated $22 million to space weather activities in FY2019.[72] NSF primarily provides grants to research institutions to conduct scientific

[69] Laurie A. Harris, CRS Analyst in Science and Technology Policy, was the lead author of this section.

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

[71] Email communication between CRS and NSF on August 13, 2019.

[72] Email communication between CRS and Robert Reese, Congressional Budget Office, on 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 FY2018 Actual $105 million amount 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

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—to improve understanding of the dynamics of the sun, Earth's atmosphere, and near-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 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.[73]

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 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."[74]

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.[75] CBO estimated that the National Aeronautics and Space Administration (NASA) allocated the majority ($264 million) of the $350 million total.[76] 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.[77]

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.

[73] Email communications between CRS and NSF on August 12, 2019; and NSF, *FY2020 Budget Request to Congress*, March 18, 2019.

[74] 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.

[75] 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.

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

[77] 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.

Legislation in the 116th Congress

The 116th Congress continues to consider and pass legislation related to space weather research, forecasting, preparedness, response, and recovery.

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

Congress enacted S. 1790 in December 2019 as the National Defense Authorization Act for Fiscal Year 2020 (2020 NDAA). The 2020 NDAA amended Sections 320 and 707 of the Homeland Security Act of 2002 (P.L. 107-296) to enact a series of homeland security-related provisions that parallel the E.O. 13865 framework for critical infrastructure resilience and emergency response. See **Table 7** for a summary of the new requirements.

Table 7. Summary of Requirements in Section 1740 of the 2020 NDAA

Department or Agency	Requirement	Deadline
Agencies supporting National Essential Functions	Update operational plans to protect against and mitigate effects of EMP/GMD	March 20, 2020
DHS (relevant SSAs)	Submit R&D Action Plan to Congress	March 26, 2020
DHS, DOD, DOE, DOC	Brief Quadrennial Risk Assessment to Congress	March 26, 2020
DHS	Provide information on EMP/GMD to federal, state, local, and private sector stakeholders	June 19, 2020
FEMA (CISA, DOE, FERC)	Develop EMP/GMD response and recovery plans and procedures	June 19, 2020
DHS (S&T, CISA, FEMA, DOD, DOE)	Pilot test of engineering approaches to mitigate EMP/GMD effects	September 22, 2020
DOD (DHS, DOE)	Pilot test of engineering approaches to harden defense installations and associated infrastructure	September 22, 2020
FEMA (CISA, DOE, FERC)	Conduct EMP/GMD national exercise	December 21, 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
FEMA	Brief Congress on state of emergency notification systems	December 21, 2020
DHS (DOD, DOE)	Report on technological capabilities and gaps	December 21, 2020
DHS (SSAs, DOD, DOE)	Review test data on EMP/GMD effects on critical infrastructure	December 21, 2020

Source: NDAA 2020 (), Section 1740.

Note: Parentheses in the first column denote a coordination requirement for the lead department or agency.

The 2020 NDAA also repealed Section 1691 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." The Congressional EMP Commission was to conduct an EMP threat assessment and make policy recommendations to Congress.[78] Senior commission members have publicly claimed a prominent role in developing E.O. 13865, which "seeks to implement core recommendations of the Congressional EMP Commission on an accelerated basis."[79] House-passed versions of the 2020 NDAA cited the publication of E.O. 13865 when repealing Section 1691.[80]

Other provisions in the 2020 NDAA require the National Guard to clarify relevant "roles and missions, structure, capabilities, and training," and report to Congress no later than September 30, 2020, on its readiness to respond to electromagnetic pulse events affecting multiple states.

The Space Weather Research and Forecasting Act (S. 881) and Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act (H.R. 5260)

These similar but not identical bills, introduced by Senator Gary Peters and Representative Ed Perlmutter respectively, set forth provisions designed to improve the ability of the United States to forecast space weather events and mitigate the effects of space weather. The bills provide statutory authority for an interagency working group (such as SWORM, which was established administratively by the NSTC in 2014). Other major provisions of the bills concern federal agency roles and responsibilities, the establishment of an advisory group, R&D, data sharing, and certain congressional reporting requirements. S. 881 also includes provisions related to the protection of critical infrastructure. The Senate Committee on Commerce, Science, and Transportation ordered S. 881 to be reported without amendment in April 2019. S. 881 was reported out of the committee and placed on the Senate Legislative Calendar in December 2019. H.R. 5260 was referred to several House committees for consideration in November 2019. Previous versions of these bills were introduced in the 114th and 115th Congresses.

Author Information

Eva Lipiec
Analyst in Natural Resources Policy

Brian E. Humphreys
Analyst in Science and Technology Policy

[78] A similarly named commission was first established by Congress in the National Defense Authorization Act for Fiscal Year 2001, and reestablished by the National Defense Authorization Act for Fiscal Year 2016. Its final report was released in 2017.

[79] Peter Pry, "Finally, a Presidential EMP Order That May Save American Lives," *The Hill*, April 26, 2019, at https://thehill.com/opinion/national-security/436224-finally-a-presidential-emp-order-that-may-save-american-lives. Dr. Pry served as chief of staff of the Congressional EMP Commission.

[80] H.R. 2500, Section 1683.

Disclaimer

This document was prepared by the Congressional Research Service (CRS). CRS serves as nonpartisan shared staff to congressional committees and Members of Congress. It operates solely at the behest of and under the direction of Congress. Information in a CRS Report should not be relied upon for purposes other than public understanding of information that has been provided by CRS to Members of Congress in connection with CRS's institutional role. CRS Reports, as a work of the United States Government, are not subject to copyright protection in the United States. Any CRS Report may be reproduced and distributed in its entirety without permission from CRS. However, as a CRS Report may include copyrighted images or material from a third party, you may need to obtain the permission of the copyright holder if you wish to copy or otherwise use copyrighted material.