NATIONAL SPACE WEATHER STRATEGY AND ACTION PLAN

Product of the

SPACE WEATHER OPERATIONS, RESEARCH, and MITIGATION WORKING GROUP

SPACE WEATHER, SECURITY, and HAZARDS SUBCOMMITTEE

COMMITTEE ON HOMELAND and NATIONAL SECURITY

of the

NATIONAL SCIENCE & TECHNOLOGY COUNCIL

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The National Science and Technology Council (NSTC) is the principal means by which the Executive Branch coordinates science and technology policy across the diverse entities that make up the Federal research and development enterprise. A primary objective of the NSTC is to ensure science and technology policy decisions and programs are consistent with the President's stated goals. The NSTC prepares research and development strategies that are coordinated across Federal agencies aimed at accomplishing multiple national goals. The work of the NSTC is organized under committees that oversee subcommittees and working groups focused on different aspects of science and technology. More information is available at http://www.whitehouse.gov/ostp/nstc.

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About the Space Weather Operations, Research, and Mitigation Working Group

The Space Weather Operations, Research, and Mitigation (SWORM) Working Group is an interagency group organized under the Space Weather, Security, and Hazards Subcommittee, which is part of the NSTC Committee on Homeland and National Security. The SWORM Working Group seeks to coordinate Federal Government departments and agencies to enhance national capabilities in promoting resilience to the effects of space weather.

About this Document

This document was developed by the SWORM Working Group. Public input into the development of this document was received through a Federal Register (83 FR 17526) request for information solicitation. Responses to the request for information, along with input from National Security Council and National Space Council staff, informed the development of the National Space Weather Strategy and Action Plan. This document was reviewed by the Committee on Homeland and National Security, and was finalized and published by OSTP. The SWORM Working Group will review, update, and reissue this document every four years or as needed.

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THE WHITE HOUSE

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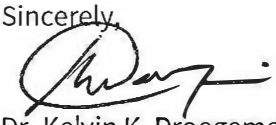
WASHINGTON, D.C. 20502

Dear Reader,

Space weather encompasses a wide array of phenomena which, though remarkable features of nature, have the potential to negatively affect and even destroy technology and infrastructure critical to our Nation's security and economy. Via coordination across the Federal Government, academia, the private sector, and international partners, the United States has made significant progress in preparing for and predicting space weather events on Earth. However, the focus of space weather activities must evolve as the Nation reinvigorates its human space exploration program, reinforces the importance of space-based capabilities for critical national functions and security, and enhances its overall resilience.

The National Science and Technology Council (NSTC), through the Space Weather Operations, Research, and Mitigation (SWORM) Working Group, has led the coordination of Federal activities to enhance American preparedness for and resilience to the effects of space weather. This National Space Weather Strategy and Action Plan provides strategic direction, identifies key actions, and calls for continued coordination across space weather and critical infrastructure stakeholders to promote American leadership in research, technology, and innovation. Through the NSTC, I am committed to coordinating the implementation of this Strategy and Action Plan across executive branch departments and agencies to build a space-weather-ready Nation.

Sincerely,



Dr. Kelvin K. Droegemeier
Director, Office of Science and Technology Policy

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Abbreviations and Acronyms

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

Use of this Document

The National Space Weather Strategy and Action Plan (Strategy and Action Plan) identifies strategic objectives and high-level actions necessary to achieve a space-weather-ready Nation. Each action includes a proposed timeline for completion. The timelines are defined as short-term (six months to two years), medium-term (two to five years), long-term (five to ten years), and ongoing (expected to be repeated within the ten-year horizon). Each action includes a list of relevant agencies, with the recommended lead agency listed first, but does not prescribe a specific approach. Participation by additional agencies not listed will benefit many actions. To achieve the objectives identified in this strategy, the SWORM Working Group will develop an internal implementation plan with specific deliverables, timelines, and metrics for success.

This strategy is intended to inform the policy development process. Any commitment of Federal resources to support the activities outlined in this document will be determined through the budget process. Strong coordination and collaboration across Federal agencies, the academic community, the private sector, and international allies and partners will improve America's ability to understand, forecast, and prepare for space weather events.

Executive Summary

Space weather comprises a set of naturally occurring phenomena that have the potential to adversely affect critical functions, assets, and operations in space and on Earth. Extreme space weather events can degrade or damage critical infrastructures, which may result in direct or cascading failures across key services such as electric power, communications, water supply, healthcare, and transportation. Preparing for space weather events will help protect infrastructure and activities vital to national security and the economy of the United States.

Under the 2015 National Space Weather Strategy and Action Plan, the Federal Government contributed to an improved understanding of space weather events and their potential effects on critical infrastructure and technologies. The 2015 Plan helped coordinate efforts to enhance research and development and to drive the improvement of operational capabilities, both forecasting and mitigation, through partnerships with the commercial sector, academia, and partner nations. As the United States seeks to increase its focus on and engage in new activities in the complex domain of space, and as the national dependence on technology continues to grow dramatically, this update to the National Space Weather Strategy and Action Plan provides an opportunity to further national preparedness for space weather events.

This National Space Weather Strategy and Action Plan (hereafter referred to as the Strategy and Action Plan) identifies key objectives and activities that will improve national preparedness for space weather events over the next 10 years. It leverages existing national efforts and seeks to align ongoing and future space weather activities to increase associated Federal Government efficiency and to enhance American innovation.

The Strategy and Action Plan seeks to achieve three objectives, each supported by a set of high-level actions, to enhance the Nation's preparedness for space weather events:

1. Enhance the Protection of National Security, Homeland Security, and Commercial Assets and Operations against the Effects of Space Weather;

2. Develop and Disseminate Accurate and Timely Space Weather Characterization and Forecasts; and

3. Establish Plans and Procedures for Responding to and Recovering from Space Weather Events.

Efforts to achieve these objectives and link outcomes among the three objectives will help safeguard national security assets and critical infrastructure, crewed and uncrewed space exploration, and foster growth in U.S. commercial space activities.

Introduction

Space weather comprises a set of naturally occurring phenomena that have the potential to adversely affect critical functions, assets, and operations in space and on Earth. Extreme space weather events can degrade or damage critical infrastructures, which may result in direct or cascading failures across key services such as electric power, communications, water supply, healthcare, and transportation. The Sun can create space weather events that have the potential to substantially disrupt or damage critical functions, assets, and operations in space and on Earth, including critical infrastructure and technology systems.[1] Solar flares, which include large eruptions of x-rays and extreme ultraviolet radiation from the Sun's surface, can temporarily degrade communications signals that transit Earth's atmosphere. Coronal mass ejections, which can launch a billion tons of solar plasma towards Earth, can create geomagnetic disturbances that last for days. These disturbances are a natural form of electromagnetic pulse, or EMP, that can cause widespread disruption or damage to the electric power grid, resulting in large-scale blackouts. Both solar flares and coronal mass ejections often occur together with solar radiation storms, which produce elevated levels of energetic particles that can be dangerous for humans in space and may pose a risk to passengers and crew in aircraft. Space weather phenomena, such as geomagnetic disturbances and solar radiation storms, may disrupt or damage electronics in exposed systems, including satellites that are critical for communications, global navigation (provided, for example, by the Global Positioning System, or GPS), national security missions, remote sensing, and other applications.

A space weather event in March 1989 triggered an electric power blackout in Canada, resulting in millions of customers without power for hours, and caused damage to some of the electric power transformers and other grid components in Canada and the United States. A series of space weather events in October 2003 disrupted infrastructure functions and technological systems across the globe, causing commercial airlines flights at high latitudes to be rerouted and electric power blackouts in Sweden. More recently, a relatively modest space weather event in November 2015 disrupted air traffic control systems in Sweden, resulting in the closing of the country's airspace for more than an hour.

In addition to their direct effects on critical infrastructure, extreme space weather events can result in cascading failures that would affect key services such as water supply, healthcare, finance, agriculture, and transportation. Though less dramatic, low-intensity space weather events occur frequently. The combined effect of these more frequent space weather events can degrade or shorten the lifetimes of infrastructure systems, increasing costs and making it more challenging to maintain reliability of service and execute national security, homeland security, and private sector operations.

Understanding and preparing for space weather events are critical to national security, the economy, infrastructure services, remote sensing, space exploration, and technology innovations that rely on communications systems and GPS for positioning, navigation, and timing services. Guided by national space weather policy, which encourages engagement with international partners, academia, and other elements of the private sector, substantial Federal activity has contributed to an improved understanding of space weather events and their potential effects on critical infrastructure and technologies. This includes the development of research programs to improve the understanding of

[1] Presidential Policy Directive 21 (PPD-21), titled "Critical Infrastructure Security and Resilience," identifies 16 critical infrastructure sectors that are so vital to the United States that their incapacitation or destruction would have a debilitating effect on national security, the economy, public health or safety, or any combination thereof.

space weather events; deployment of new research platforms in space and on the ground; development and deployment of forecast models that spans the Sun to Earth; and deployment of observation platforms that inform forecasting capabilities. Federal departments and agencies (hereafter, referred to collectively as agencies) have worked together to develop space weather benchmarks[2] that quantify the intensity of an extreme space weather event, conduct a socio-economic analysis of the potential consequences of a space weather event, and share space radiation data from the GPS constellation of satellites to improve the research and development (R&D) needed to improve operational forecast models. Together, these efforts have increased awareness of and enhanced national preparedness and planning for the effects of space weather, strengthened global collaboration with partner nations, and furthered U.S. leadership in the space and hazard preparedness domains.

This National Space Weather Strategy and Action Plan (hereafter referred to as the Strategy and Action Plan) provides a framework for continued Federal coordination and engagement to address gaps and opportunities identified across national policies. This includes promoting American resilience to the effects of space weather with a focus on critical infrastructure; enhancing operational capabilities to bolster national security; and further developing technologies and capabilities to support human exploration and commercial space activities. This Strategy and Action Plan integrates and seeks to inform the implementation of elements from the 2017 National Security Strategy, Space Policy Directive-1 (SPD-1) titled "Reinvigorating America's Human Space Exploration Program" (December 2017), and SPD-3 titled "National Space Traffic Management Policy" (June 2018).

The National Security Strategy calls for promoting American resilience through improved risk management, building a culture of preparedness, reducing vulnerability of U.S. critical infrastructure to electromagnetic attacks, and improving plans through exercises. Additionally it identifies the need for America to lead in research, technology, and inventions through collaborations with allies and partners, leveraging private capital and expertise, and rapidly fielding innovations. The National Security Strategy also identifies the need for the United States to maintain leadership and freedom of action in space, including advancing space as a priority domain, promoting space commerce, and maintaining the lead in exploration. Enhanced resilience to space weather events will contribute to these elements of National Security Strategy.

SPD-1 calls for the Nation to lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. SPD-3 calls for the Federal Government to establish an updated architecture for space traffic management, enhance space situational awareness, and provide associated data in a way that encourages innovation and maintains American leadership in space. Enhanced resilience to space weather events will help enable implementation of these national space policies. This is part of broader American resilience, and is critical to sustainable space operations, exploration, and commercialization.

The Strategy and Action Plan establishes three key objectives to better prepare the Nation for the effects of space weather:

[2] NSTC, SWORM Subcommittee, Space Weather Phase 1 Benchmarks, June 2018, https://www.whitehouse.gov/wp-content/uploads/2018/06/Space-Weather-Phase-1-Benchmarks-Report.pdf

Objective I: Enhance the Protection of National Security, Homeland Security, and Commercial Assets and Operations against the Effects of Space Weather

Space weather poses a risk to civilian critical infrastructure, defense and intelligence systems, and military operations. Strengthening critical infrastructure security and resilience to space weather events requires an understanding of and a reduction in critical infrastructure vulnerabilities to the effects of space weather. Space weather can damage or disrupt space-based assets, jeopardize or impair crewed and uncrewed space activities, and adversely affect the ability to track objects in space. Understanding vulnerabilities to and protecting against the effects of space weather should inform satellite and spacecraft owners' and operators' design and engineering plans, mitigation strategies, and operational decision-making in the space environment. Space weather effects on ground systems, such as radars, or space-, air-, and ground-based communication links, pose a risk to national and homeland security. Developing and refining strategies to protect against and mitigate the potential disruptive effects of space weather, such as hardening critical assets, can minimize space weather risks and enhance resilience.

Objective II: Develop and Disseminate Accurate and Timely Space Weather Characterization and Forecasts

Timely and accurate space weather characterization and forecasts are critical to inform the planning, execution, and decision-making of operations for a diverse set of stakeholders including critical infrastructure owners and operators, the military, and private sector satellite owners and operators. Improved understanding, observations, forecasts, and models for space weather events can lead to better quality and more timely space weather products and services as well as contribute to supporting safe, stable, and sustainable space activities.

Objective III: Establish Plans and Procedures for Responding to and Recovering from Space Weather Events

The ability to rapidly respond to and recover from extreme space weather events requires coordinated efforts and established plans and procedures. Conducting exercises to test and validate these plans and strategies can allow relevant stakeholders to practice and refine them. An improved understanding of critical system and asset vulnerabilities to the effects of space weather (Objective I), and a robust forecasting capability that can enable more timely and accurate services and products (Objective II) are important to inform Federal, State, local governments', private sector and others' efforts, capabilities, and investments in managing space weather events.

Objective I: Enhance the Protection of National Security, Homeland Security, and Commercial Assets and Operations against the Effects of Space Weather

The evolving dependence on technology and infrastructure systems coupled with the increasing degree of interconnectedness of these systems has increased the vulnerability of the Nation. There is a need to assess and address the vulnerabilities of national security capabilities to space weather events, including prioritizing risk management of national security mission planning and situational awareness.

The outcomes of these activities will serve as key inputs to manage the risk of space weather events. To enhance the resilience of the American homeland and national security assets to the effects of space weather, the Federal Government should work with partners to achieve the following:

Improve the Understanding of and Assess Vulnerabilities of Critical Infrastructures and National Security Assets to Space Weather Events

A more thorough assessment is needed to identify the vulnerabilities of critical infrastructure systems and national security assets, representative of those deployed across the globe, to the effects of space weather events. Assessing vulnerabilities can inform efforts to identify and protect those infrastructure systems, assets, and technologies at greatest risk to space weather and inform pragmatic approaches to enhance national preparedness. Obtaining an actionable understanding of the effects of space weather and the way it can affect individual systems and propagate across interconnected systems and assets requires improved models. In addition to models, benchmarks of space weather phenomena can provide useful input for creating engineering standards, developing vulnerability assessments, establishing decision points and thresholds for action, understanding risk, developing more effective mitigation procedures and practices, and enhancing response and recovery planning and the execution of the national security mission, national critical functions, and national essential functions.

1.1 Refine space weather benchmarks that provide quantitative baselines to assess the intensity of space weather events. This includes refining the Phase 1 Benchmarks that were released by the National Science and Technology Council in 2018 for induced geo-electric fields, ionizing radiation, ionospheric disturbance, solar radio bursts, and upper atmospheric expansion. These benchmarks should be in a form useful to the owners and operators of systems and assets that contribute to critical national functions. [Mid-term; Department of Commerce (DOC), Department of Defense (DOD), Department of Energy (DOE), Department of Homeland Security (DHS), Department of the Interior (DOI), Department of State (DOS), Department of Transportation (DOT), Federal Communications Commission (FCC), National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF)]

1.2 Assess the vulnerability of priority critical infrastructure systems and national security assets to the effects of space weather and use the results to inform risk management. Vulnerability assessments should include interdependencies and failure modes among sectors that could contribute to cascading failures. This action should include assessments of national critical functions and associated priority critical infrastructure and national security systems, assets, and networks, representative of those deployed across the globe and in space. Federal agencies should work with private sector critical infrastructure owners, operators, and users, as appropriate, prioritizing national security assets and the energy, communications, and financial sectors. This action should also include efforts to develop hazard maps of the United States and space to improve estimations of how space weather

can affect technology. [Mid-term; DHS, DOC, DOD, DOE, DOI, DOT, Environmental Protection Agency (EPA), Department of Health and Human Services (HHS), Department of Treasury (Treasury), DOI, and Nuclear Regulatory Commission (NRC)]

1.3 Model the effects of space weather on space-, air-, and ground-based national critical functions and associated priority critical infrastructure and national security systems, assets, and networks. This action should include efforts to identify existing and develop new operational models that predict space weather effects on infrastructure. This action will help inform the effectiveness of mitigation approaches and should seek nationwide or global models, as appropriate. In conducting this research and development, Federal agencies will work with academia and private sector critical infrastructure owners, operators, and users, as appropriate, to test and validate these models. [Mid-term; DHS, DOC, DOD, DOE, DOI, DOS, DOT, EPA, HHS, NASA, NRC, NSF, and Treasury]

1.4 Identify and assess the effects of frequent and extreme space weather events on operations and missions. To better quantify and manage the risk space weather poses to critical assets and national security missions, there is a need to identify and assess the consequences of both direct and indirect effects of space weather. Complemented by the vulnerability assessments conducted in action 1.2 and the system modeling developments in action 1.3, these assessments can support a more holistic understanding of risks to inform planning activities for extreme and routine space weather events. [Mid-term; DOD/DHS, and DOC]

1.5 Assess the cost of space weather effects on the operations and implementation of critical missions. Space weather events—both frequent, lower-intensity events and extreme events—can negatively affect the execution of critical operations and missions. These effects can range from delay and avoidance to replacement of damaged systems. Agencies should assess the cost of space weather on the implementation of critical missions to better prioritize investments to mitigate the effects of space weather. [Mid-term; DHS, DOC, DOD, DOE, DOI, DOS, DOT, EPA, HHS, NASA, and Treasury]

Develop and Test Technologies that Protect and Mitigate Critical Systems and Assets

Developing and deploying methods, techniques, and technologies is important for minimizing and mitigating the potential consequences of space weather events, both frequent and extreme. Activities to harden or increase the resilience of homeland and national security critical assets and systems in space, air, and on the ground are key for preparing the Nation against the effects of space weather.

1.6 Identify and prioritize R&D necessary to enhance the security and resilience of critical functions and national security assets to the effects of space weather. Identifying R&D gaps in science and engineering can inform efforts to mitigate and address space weather risks on critical functions and assets. Agencies should work across Federal laboratories, the private sector, and academia, as appropriate, to identify and prioritize R&D needs to improve the security and resilience of infrastructure systems, assets, and networks that provide critical national functions and support the national security mission. This should include identifying new designs or engineering approaches that enable systems to withstand the effects of space weather, informed by the results of 1.4. [Short-term; DHS, DOC, DOD, DOE, HHS, NASA, and NSF]

1.7 Test, evaluate, and deploy technologies and devices to mitigate the effects of space weather on critical functions and assets. This action should include Sector Specific Agencies'[3] plans and pilot programs to test devices that mitigate the effects of space weather on communication systems, geomagnetic disturbances on the electrical power grid, or radiation events on satellites. It should also include the development of processes to improve the transition of research approaches to operations, and utilize incentives and cost recovery mechanisms to encourage private sector participation. [Mid-term; DHS, DOC, DOD, DOE, HHS, and NASA]

1.8 Support the development and use of standards for improved resilience of equipment to space-weather events. Through participation in cross-sector, multilateral, or bilateral fora, the United States should seek to encourage the development of relevant open, consensus-based international standards that focus on improving resilience of equipment. These standards should include designing and engineering resilience into equipment or identifying best practices for shielding or hardening infrastructure systems, assets, and networks to the effects of space weather. [Ongoing; DHS, DOC, DOD, DOE, DOS, DOT, HHS, NASA, and NRC]

[3] Each of the 16 critical infrastructure sectors defined in PPD-21 is assigned a Sector-Specific Agency that has specialized knowledge about the sector. Each Sector-Specific Agency helps its designated sector coordinate and collaborate with the Federal government to strengthen security and resilience of critical infrastructure.

Objective II: Develop and Disseminate Accurate and Timely Space Weather Characterization and Forecasts

Timely and accurate characterization[4] and forecasting of how and where space weather events change the operational environment in space and on Earth will enhance the security and resilience of critical infrastructure and improve the ability to protect national security assets. Industry uses characterizations and forecasts to inform operations, such as modifications to electric power grid operations, changes in commercial flight paths, delaying surveying and oil drilling operations, and modifying activities in space. Providing regional and global characterization of space weather conditions, which can affect communications, surveillance, and navigation, helps enable the execution of national security missions across all domains. Developing and advancing forecasting capabilities with increased accuracy, lead-time, and geographic resolution will enable more effective mitigation approaches and can contribute to efforts to protect space-based assets and operations, foster a safer and more sustainable space environment for human exploration and commercial space endeavors, and protect and support the national security missions.

To sustain and enhance the national capability to provide timely characterization and forecasts of space weather and its effects, the Federal Government should work with partners to achieve the following:

Identify and Ensure Baseline Observational Capabilities

Timely and accurate space weather products and services are key inputs to inform operational procedures for national security missions, space operations, and critical infrastructure services, such as electric power grid operations, commercial aviation, and tactical communications. Understanding how the Sun, Earth, and interplanetary space are connected as a system, and making relevant observations of this system, are the indispensable foundation of these products and services. To ensure adequate and sustained real-time observations for space-weather analysis, forecasting, and decision-support services, the Federal Government will identify a baseline operational observation capability. The observational baseline should specify the optimal mix of ground-based and space-based observations to enable continuous and timely space weather products and services. The associated data reception, relay, processing, assimilation, and archiving infrastructure required to utilize space-weather observations must be included in the baseline.

2.1 Identify baseline ground-based, sea-based, air-based, and space-based operational observation capabilities. Identifying and establishing a baseline is necessary to prioritize critical observation capabilities that contribute to the current operational suite of space weather products and services. This baseline can enable the development and refinement of products and services necessary to inform the protection of systems, services, and assets that contribute to national security operations and national critical functions. [Short-term; DOC, DOD, DOI, DOS, NASA, and NSF]

2.2 Ensure baseline operational space weather observation platforms, capabilities, and networks. Observations are critical to enable timely and accurate forecasting. This action should include efforts to sustain baseline observation capabilities and identify opportunities to increase their reliability, utilize new technologies, and reduce their cost through

[4] Characterization includes measurement, assessment, and modeling of the space weather environment to inform now-casts, situational awareness, historical studies and forensics, and attribution.

partnerships with the private sector, academia, and international partners, as appropriate. [Ongoing; DOC, DOD, DOI, DOS, NASA, and NSF]

Improve Observations and Modeling for Characterization and Forecasting

Improving the understanding and forecasting of space weather events requires enhancing existing capabilities, deploying new and innovative observational platforms and technologies, and leveraging private sector partnerships and international engagement, where appropriate. Continuing scientific and technological advancements will enable further enhancement of observational and modeling capabilities beyond the minimally sufficient baseline identified in Action 3.1. Coordinating and maintaining support for this work will provide opportunities to improve the accuracy and the lead-time of space weather forecasts. Additionally, improving the understanding and characterization of the effects space weather phenomena have on Earth and in the space environment can improve situational awareness, informing decision-making and enabling the execution of missions that depend on technologies and services susceptible to disruptions from space weather.

The Nation has invested in the development of research infrastructure and predictive models to meet the needs of a growing space-weather user community, however, existing modeling capabilities still fall short of providing what is needed to meet these demands. To fully realize the benefits of its research investments, the Nation should develop improved research models targeted to operational needs, transition these research models to operational models, and incorporate them into operational forecasts.

2.3 **Support and coordinate opportunities for fundamental research in heliophysics and geospace sciences**. Understanding the underlying physical processes of the Sun that drive space weather events, and processes in Earth's near space environment, are necessary to improve forecasting and enhance preparedness efforts. [Ongoing; NASA, DOI, and NSF]

2.4 **Identify, develop, and test innovative approaches to enable enhanced, more informative, robust, and cost-effective measurements.** Improved measurements may provide enhanced information about a variety of space weather phenomena, which can be used to improve forecast lead-time, accuracy, and geographic resolution. Opportunities for improving measurements include increased spatial and temporal resolution, fidelity, promptness, and measurement system reliability. This action should include the utilization of new or additional measurements provided by the private sector and the development of novel observational approaches in partnership with the private sector and international partners, where appropriate. This action should prioritize approaches that provide the most improvement to space weather forecasting and characterization capabilities. [Short-term; NASA/NSF, DOC, DOD, DOI, and DOS]

2.5 **Enhance current space weather models and develop improved modeling techniques for space weather.** Testing and validation of forecasts and models is critical to ensuring their relevance and accuracy. Key tasks for completing this action include enhancing data integration and utilization, developing metrics to measure and evaluate the performance and capabilities of operational and scientific models, supporting R&D to improve models, and identifying computational resource requirements for openly running and testing operational models. [Mid-term; DOC/NASA, DOD, DOE, DOI, and NSF]

2.6 **Identify and release, as appropriate, new or previously underutilized data sets.** Greater access to existing data sets could improve the development, validation, and testing of models

used for characterizing and forecasting space weather events. Examples of underutilized data sets include historical space weather relevant data from U.S. Government satellites, U.S. Government funded ground-based observatories and networks, and in situ measurements throughout the electric power grid. [Short-term; DOD, DOC, DOE, DOI, NASA, and NSF]

2.7 **Identify mechanisms for sustaining and transitioning models and observational capabilities from research to operations.** Transitioning models from research to operations and leveraging operations to identify gaps in research is critical to improving operational space weather forecasts and services. Mechanisms for completing this action should include leveraging existing capabilities and centers, such as the DOC Space Weather Prediction Center, NASA Community Coordinated Modeling Center, or the Joint Center for Satellite Data Assimilation, or creating a more formal framework to enhance and accelerate the transition from research to operations, including academic, private sector, and international partnerships, where appropriate. [Ongoing; DOC, DOD, DOS, NASA, and NSF]

Ensure Timely Dissemination of Characterizations and Forecasts Useful to Consumers

Timely notifications of an impending space weather event and its potential effects on the Nation's critical infrastructure and space-, air-, and ground-based national security assets are key to preparing for the effects of space weather. These notifications must be disseminated and communicated to decision-makers in a readable and usable format.

2.8 **Enhance accessibility and sharing of observational data across the stakeholder community.** Increased access to government, civilian, and commercial space-weather observational infrastructure and data across the globe is of mutual benefit to the United States and its partners. Cross-sector and international cooperation in the observation and characterization of space weather events will enhance global preparedness. [Short-term; DOS/DOC, DOD, DOI, NASA, and NSF]

2.9 **Improve the effectiveness of space weather event notifications**. Improving the overall effectiveness of space weather notifications may require strengthening mechanisms for their communication, dissemination, and coordination. It may also require educating the public and other recipients of these notifications regarding the potential effects of space weather and appropriate responses in the event of notification. This action can include ensuring that space weather events do not prevent dissemination of space weather products to consumers. To the extent feasible, notifications should include information content that will enable rapid selection and implementation of pre-planned response measures. In completing this action, the Federal Government will coordinate with State, local, and Tribal governments, private sector users and operators, international partners, and the media, as appropriate. [Short-term; DOC, DHS, DOD, DOE, DOS, and NASA]

2.10 **Engage international partners to ensure space weather products and services are globally coordinated and consistent, as appropriate, during extreme events**. As a leader in space, the United States will continue to work through international fora such as the United Nations Committee on the Peaceful Uses of Outer Space[5] and the World Meteorological

[5] Within the United Nations General Assembly, the Committee on the Peaceful Uses of Outer Space (COPUOS) governs the exploration and use of outer space. Their mandate is to strengthen international legal regimes that govern space and to support efforts that maximize the benefits of space science and technology.

Organization[6] to coordinate the consistent messaging and communication of space weather events. This action should include the potential development of international standards for exchanging space weather data. [Ongoing; DOS, DOC, DOD, and NASA]

2.11 Develop and refine situational awareness capabilities. Robust situational awareness capabilities can enable the effective execution of missions, and the rapid detection, warning, characterization, and attribution of natural versus man-made disturbances to technologies and infrastructure systems critical to national and homeland security. This action should include developing systems that provide new or additional real-time information pertaining to satellite anomalies. [Mid-term; DOC, DHS, DOD, DOE, DOS, DOT, EPA, NASA, and Treasury]

[6] The World Meteorological Organization (WMO) is a specialized agency of the United Nations that is responsible for assessments and international policies regarding the behavior of the Earth's atmosphere and its interaction with terrestrial assets.

Objective III: Establish Plans and Procedures for Responding to and Recovering from Space Weather Events

Establishing, exercising, and enhancing operational plans and procedures to address the threat of space weather will improve mitigation, response, and recovery capabilities. Validating operational plans and procedures through measurement, realistic tests, and exercises is critical to ensuring their effectiveness. Actions to improve the understanding of vulnerabilities to and effects of space weather on critical systems and assets, as identified in Objective I, can reduce uncertainties in planning and mitigation strategies for space weather events. Vulnerability assessments should inform operational procedures and tests. As new technology enhances modeling or real-time monitoring of space weather effects, updates to procedures and testing should follow. Testing these plans and procedures through coordinated exercises can provide valuable insights for key stakeholders to validate and refine their plans.

To establish and enhance plans and procedures for responding to space weather events, the Federal Government should work with stakeholders, as appropriate, to achieve the following:

Improve Planning for Space Weather Events

The National Security Strategy identifies improved planning as a key component of resilience. Performing realistic simulations and exercises can help validate mitigation strategies and preparedness activities that are needed before, during, and after a space weather event. Exercises can increase awareness and improve the understanding of the effects of space weather on the Nation's critical infrastructure, services, and functions. The feedback and lessons learned can improve the implementation of preparedness activities.

3.1 Develop, review, and update Federal response plans, programs, and procedures to address the effects of space weather. Integration of space weather products into national preparedness strategies and procedures is important to enable a coordinated response to space weather events. To the extent feasible, Federal hazard preparedness plans and programs should account for space weather events and their potential effects. For example, these plans should incorporate information gathered from the refined benchmarks and vulnerability assessments identified in Objective I. [Mid-term; all Federal departments and agencies that support national critical functions and the national security mission]

3.2 Develop and disseminate products and information on the effects of space weather that support coordinated response and recovery efforts. Enhancing the understanding and awareness of the potential disruptive effects of space weather is key to promoting the integration of space weather into planning and mitigation strategies. For example, guidance on emergency management protocols during response to space weather events can support efforts to execute a coordinated national and global response. [Ongoing; DHS/DOS, DOC, DOD, and NASA]

3.3 Facilitate information sharing to inform and enhance the operation and restoration of critical infrastructure at greatest risk to the effects of space weather. Sharing information on the effects of space weather on space-, air-, and ground-based systems can inform operations, research, and models. Mechanisms to disseminate data on these effects and information that inform best practices for preparedness can contribute to whole-of-community coordinated approaches to mitigate space weather effects and enhance the operation and restoration of critical infrastructures and national security assets at greatest risk. This should include the development and sustainment of a database for satellite anomalies, such as temporary upsets in function, loss of communications, or failure of the satellite, which can be used to better understand the effects of space weather on satellite operations. [Ongoing; DHS, DOC, DOD, DOE, DOI, DOS, DOT, EPA, HHS, NASA, and Treasury]

Test and Evaluate Plans and Procedures for Space Weather Events

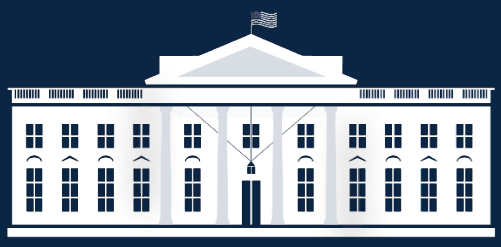
Space weather is a global hazard that can affect infrastructures, systems, and assets across sector, regional, state, and international boundaries. Comprehensive guidance for improving operational protocols to enhance preparedness capabilities must consider the increasing interconnectedness of infrastructure systems. Additionally, increasing the awareness of space weather benchmarks and space weather attribution, characterization, and forecasting capabilities can enhance time-sensitive operational procedures.

3.4 Assess executive and statutory authority regarding the ability to direct, suspend, or control critical infrastructure operations, functions, and services before, during, and after space weather events. This will inform the development of operational plans to protect against, mitigate, respond to, and recover from the effects of space weather, prioritizing the lifeline functions that include communications, energy, transportation, and water management. For example, this should include the Department of Energy assessing their ability to protect or restore the reliability of critical electric infrastructure during a grid security emergency driven by a geomagnetic disturbance. [Short-term; DHS, DOC, DOD, DOE, DOI, DOT, EPA, NRC, and Treasury]

3.5 Exercise Federal response, recovery, and operations plans and procedures for space weather events. Periodic simulation and exercise that covers reaction to forecasts, mitigation, response, and recovery activities can improve the ability of key Federal stakeholders to prepare for space weather events. These activities may benefit from engagement with international, State, local, tribal, and territorial governments and the private sector, as appropriate. The results of the exercises could inform updates and revisions to appropriate Federal operating concepts and other relevant planning documents. [Ongoing; DHS, DOC, DOD, DOE, DOS, DOT, and NRC]

Conclusion

Space weather poses a constant threat to the Nation's critical infrastructure, our satellites in orbit, and our crewed and uncrewed space activities. Extreme space weather events can cause substantial harm to our Nation's security and economic vitality. This Strategy and Action Plan provides a collaborative and federally coordinated roadmap for strengthening our resilience to space weather events. Achieving the objectives in this Strategy and Action Plan will require coordination and collaboration within and across the Federal Government, as well as engagement with the commercial sector, academia, and like-minded nations. Preparing for space weather events is an important aspect of American resilience that bolsters national and homeland security and facilitates continued U.S. leadership in space.



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