Findings and Recommendations to Successfully Implement PROSWIFT and Transform the National Space Weather Enterprise

April 17, 2023

Executive Summary

In October 2020, Congress passed the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act (PROSWIFT Act; P.L. 116-181; 51 USC §§60601-60608) with bipartisan support and support across the national space weather enterprise, which comprises the Federal Government, the commercial sector, and the academic sector. PROSWIFT defines the roles and responsibilities of the Federal departments and agencies, codifies the White House led interagency working group (i.e., the Space Weather Operations, Research, and Mitigation (SWORM) subcommittee), and directs the National Oceanic and Atmospheric Administration (NOAA), working with SWORM, to establish a Space Weather Advisory Group (SWAG). In April 2021, NOAA chartered SWAG which consists of five members each from academia, the commercial sector, and non-governmental end users. SWAG was chartered to advise SWORM on a variety of space weather issues including the development and implementation of an integrated strategy for space weather (i.e., the National Space Weather Strategy and Action Plan).

In June 2022, SWORM advised SWAG that they were initiating an update to the National Space Weather Strategy and Action Plan and tasked SWAG to provide input. SWAG members reviewed the 2015 and 2019 National Space Weather Strategy and Action Plans, the White Paper on the Implementation Status of the National Space Weather Strategy and Action Plan, and the Decadal Survey on Solar and Space Physics 2024-2033 white papers in developing input to SWORM. One of the roles of SWAG is to provide a mechanism for broader community input to the Federal Government activities and planning. Therefore, on January 18-20, 2023, SWAG held a hybrid, open meeting in Washington DC with invited speakers and time for public input as part of their information gathering process. The meeting was divided into seven panel discussions: Observational Data and Access (Ground-based and Airborne); Economic Assessments; Observational Data, Access, and Infrastructure in Space; Benchmarks, Metrics, and Scales; Data Infrastructure and Methods; Evolving Infrastructure Systems and Services; and Industry and Government Collaborations, Coordination, Outreach, and Communications on Space Weather. Each of the panels consisted of 3-5 speakers with ample time for committee discussion.

SWAG wishes to thank the individuals, both panelists and members of the public, who spoke at the January 2023 meeting. SWAG also wishes to thank SWORM members who attended and participated in the meeting. All the input was considered by SWAG and contributed to making this report better.

Since the publication of the first National Space Weather Strategy, the national space weather enterprise has made noteworthy progress on improving awareness of space weather and its effects, understanding and forecasting space weather, and planning for space weather events.

However, substantial investments are needed to build resilience and ensure space weather services can continue to improve and meet the growing and changing needs of the Nation.

To this end, SWAG identified 25 findings with 56 recommendations which, if implemented, will provide the funding, processes, support, and structure to foster transformative change across the national space weather enterprise. SWORM asked SWAG to prioritize among the recommendations. Below are the 11 highest priority recommendations listed in the order they appear in this report (not ranked by highest priority). The findings associated with these recommendations and additional information on each can be found in the appropriate sections of the report noted in the bolded parentheses.

Priorities

1. **Fund the Federal Space Weather Enterprise.** The Federal space weather enterprise is insufficiently funded to implement PROSWIFT actions, perform the codified roles and responsibilities, or appropriately address the risk space weather poses to the Nation. These risks have grown and continue to grow as new technology is adopted that can be affected by space weather. The executive branch should work with Congress to identify new and sustained funding to address these shortfalls. **(R.1.1.)**

2. **Create and fund an applied research program office for space weather within NOAA to coordinate, facilitate, promote, and transition applied research across the national space weather enterprise.** NOAA is not properly structured to meet their goal of addressing the critical societal challenge that space weather poses. NOAA should establish and fund an office within the NOAA Division of Oceanic and Atmospheric Research focused on space weather research necessary to complement and support the space weather roles and missions of NOAA NWS and NESDIS, and to achieve the roles and responsibilities outlined in PROSWIFT, the Weather, Water, and Climate Strategy for FY 2023-2027, and other relevant policies. This new office should coordinate, facilitate, fund, and promote academic and private sector applied research across the national space weather enterprise. **(R.2.1.)**

3. **Ensure OSTP staffing and White House led prioritization and coordination across the national space weather enterprise.** The White House Office of Science and Technology Policy (OSTP) needs to sufficiently staff and prioritize space weather, to maximize budget opportunities and progress towards resilience. OSTP should redouble efforts to further improve coordination and align budget priorities among SWORM agencies and space weather activities and roles across the federal interagency. This will require sustained staffing of a full-time equivalent, preferably by someone with space weather expertise. **(R.3.1. and myriad other coordination-focused recommendations throughout)**

4. **Protect space weather sensors from spectrum interference.** Space weather sensors are vulnerable to and potentially at risk of spectrum interference from electromagnetic emissions (e.g., radio frequency) originating from technology systems (e.g., 5G applications). SWORM should coordinate the establishment of domestic and global protections for space weather sensors akin to terrestrial weather sensors. **(R.5.1.)**
5. **Provide long-term support for operational ground-based and airborne sensors and networks.** NOAA should fundamentally change the way ground-based and airborne sensors and networks are prioritized, supported, and maintained, including those operated by academic and commercial sectors, to enable operational products and services and meet NOAA's statutory role. **(R.6.2.)**
6. **Provide and fund critical operational space weather services beyond near-Earth.** NOAA should seek increased funding and partnerships (e.g., Department of Defense, NASA, and commercial or international partners) to support an expanded in-space architecture to meet growing national needs in these regions. This includes meeting near-Earth operational needs and expanding support and funding for space weather services in medium-Earth orbit, geostationary Earth orbit, geostationary transfer orbit, cis-Lunar, and eventually Martian environments. NOAA will need to determine the in-space infrastructure needed to support space weather services in these regions. **(R.9.2.)**
7. **Fund NASA missions that advance fundamental science to support space weather research.** NASA should seek increased funding to support coordinated and integrated space weather fundamental research missions that address well-rounded space weather fundamental science. Funding in support of space weather research missions should be commensurate with the risk space weather events pose. **(R.10.1.)**
8. **Coordinate benchmark development or improvement with industry.** For industries with mature space weather benchmarks, SWORM should reconcile government and industry benchmarks to ensure the latest research and knowledge from industry and the space weather enterprise is applied and can be expressed in terms and parameters that are applicable to end users. Where there are no mature industry benchmarks, SWORM should involve industry in the development of new benchmarks. **(R.14.1.)**
9. **Quantify the societal benefits for addressing risk from space weather by performing national-level and industry-wide economic assessments and consider space weather in the context of broader national risk.** Economic assessments and national-level risk assessments should be conducted to quantify risk and ensure the national space weather enterprise is funded at a level commensurate with the risk it poses to the Nation and society. **(R.18.1.) and (R.4.1.)**
10. **Support coordinated applied research within the thermosphere (above 100 km altitude) which is critical for space traffic coordination.** There is an immediate and growing need for baseline models and data streams from across the national space

weather enterprise for improving space traffic coordination and avoiding the negative consequences of space weather on the growing number and importance of space assets in low-Earth orbit (LEO). **(R.24.1-3.)**

11. **Foster and lead a global space weather enterprise.** The U.S. Federal Government (through the State Department) should develop and implement an international process (through the United Nations or similar entity) that seeks more opportunities to globally unify priorities, collaborate, coordinate, and co-fund observations and capabilities with partner and allied nations around the world, broadening international engagement, collaboration, and coordination to meet the growing global need for space weather products. This is needed to effectively address the growing global importance of space weather and the cost to address it. **(R.25.1-4.)**

SWAG looks forward to engaging SWORM agencies and other relevant stakeholders on these findings and recommendations. SWAG looks forward to advising SWORM on the implementation of these findings and recommendations and any subsequent update or reevaluation of the National Space Weather Strategy and Action Plan, or other relevant plans, policies, or strategies, pursuant to 51 USC 60601(d)(2)(D).

The findings and recommendations in this report are not yet informed by the results of the user-needs surveys SWAG is conducting pursuant to 51 USC 60601(d)(3). SWAG will develop additional findings and recommendations, as appropriate, based on the results of these surveys. SWAG will also review or develop new findings and recommendations as appropriate or at the request of Congress or SWORM.

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CHAPTER 1: Introduction

Space weather is a naturally occurring phenomenon, primarily originating from the Sun, which has the potential to cause significant negative effects to a variety of technologies and critical infrastructure sectors. The most significant space weather events are associated with solar flares and coronal mass ejections and can affect technologies critical to the economy and security of the United States and nations around the world. Technologies such as the electric power grid, the Global Positioning System (GPS), satellite and other space activities, communications, aviation, and pipelines may be degraded or disrupted during space weather events. A 2017 study indicates that the global economic impacts from an intense space weather event could range from $2.4 to 3.4 trillion over a year. As the Nation becomes increasingly dependent on technologies vulnerable to space weather, it is imperative to take prompt action to further improve the understanding, monitoring, forecasting, and mitigation of this hazard. Appropriate and timely action will reduce risk and enhance national resilience for space weather events.

Historical Context

The National Aeronautics and Space Administration (NASA) Authorization Act of 2010 recognized space weather as a risk to modern technological systems that could have significant societal, economic, national security, and health effects. The Act required the Director of the White House Office of Science and Technology Policy (OSTP) to improve the Nation's ability to prepare for, avoid, mitigate, respond to, and recover from the potentially devastating effects of space weather events. With this charge and amid growing geopolitical and strategic interest in space weather, in 2014 OSTP formally chartered the Space Weather Operations, Research, and Mitigation (SWORM) Task Force (and subsequent Subcommittee) under the National Science and Technology Council (NSTC) to coordinate actions to address space weather risk. SWORM is co-chaired by OSTP, the Department of Commerce, and the Department of Homeland Security. It is composed of members from over 20 Federal departments and agencies, including the Office of Management and Budget (OMB) and the National Security Council. The establishment of SWORM was the first time the science, national security, and preparedness communities were seated at the same table to strategically address the risk of space weather across the Federal enterprise. SWORM was tasked with developing a national strategy and action plan to address this risk.

In developing the first National Space Weather Strategy and Action Plan, SWORM built on previous work from the space weather, national security, and preparedness communities and leveraged relevant U.S. frameworks and authorities including Presidential Policy Directive (PPD) -21 Critical Infrastructure Security and Resilience and PPD-8 National Preparedness. SWORM wanted an all-of-community strategy, and thus requested public input as it was preparing the first strategy and action plan.

In October 2015, the White House hosted an event to launch the National Space Weather Strategy and National Space Weather Action Plan and to highlight industry and government commitments to improve U.S. preparedness for space weather events. The Strategy and Action Plan "articulate how the Federal Government will work to enhance national space-weather preparedness by coordinating, integrating, and expanding existing policy efforts; engaging a broad range of sectors; and collaborating with international counterparts" (OSTP, 2015). This was a critical step in enhancing national and international preparedness for space weather events.

The 2015 Strategy identified six high-level goals: (1) establish benchmarks for space weather events; (2) enhance response and recovery capabilities; (3) improve protection and mitigation efforts; (4) improve assessment, modeling, and prediction of impacts on critical infrastructure; (5) improve space weather services through advancing understanding and forecasting; and (6) increase international cooperation. The Action Plan identified approximately 100 distinct activities with associated deliverables and timelines (ranging from 4 months to 5 years) to achieve the six goals identified in the Strategy. The Action Plan assigned each activity to at least one Federal agency and emphasized the need for collaboration with industry, academia, and other nations.

In 2016, the President signed Executive Order 13744 on Coordinating Efforts To Prepare the Nation for Space Weather Events to solidify national space weather policy, formalize executive branch agencies' roles and responsibilities for space weather preparedness, and further identify actions necessary to improve national preparedness to space weather events.

In 2019, SWORM updated the National Space Weather Strategy and Action Plan to focus on resilience to space weather effects. The 2019 Strategy and Action Plan had 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.

Not long after the release of the 2015 National Space Weather Strategy and Action Plan, Congress began developing authorization legislation to codify many of the strategy's elements. The effort took over five years to come to fruition. In October 2020, Congress passed the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act (PROSWIFT Act; P.L. 116-181; 51 USC §§60601-60608) with bipartisan support and support across the national space weather enterprise, which comprises the Federal Government, the commercial sector, and the academic sector. Congress has yet to sufficiently appropriate the roles and activities codified by PROSWIFT.

PROSWIFT defines the roles and responsibilities of the Federal departments and agencies, codifies SWORM, and directs the National Oceanic and Atmospheric Administration (NOAA), working with SWORM, to establish a Space Weather Advisory Group (SWAG). In April 2021, NOAA chartered SWAG (see Appendix 2) which consists of five members each from academia, the commercial sector, and non-governmental end users (see Appendix 3).

Role of SWAG

SWAG was chartered to advise SWORM on a variety of space weather issues including the development and implementation of an integrated strategy for space weather (i.e., the National Space Weather Strategy and Action Plan). According to the PROSWIFT Act, the strategy shall identify: (1) observations and measurements that must be sustained beyond the lifetime of current ground-based and space-based assets that are essential for space weather research, models, forecasting, and prediction; (2) new observations and measurements that may significantly improve space weather forecasting and prediction; and (3) plans for follow-on space-based observations.

In June 2022, SWORM advised SWAG that they were initiating an update to the National Space Weather Strategy and Action Plan and tasked SWAG to provide input. In January 2022, SWORM provided SWAG with a status summary of the efforts made to date to achieve the objectives outlined in the 2019 National Space Weather Strategy (White Paper on the Implementation Status of the National Space Weather Strategy and Action Plan). For each objective and action, SWORM outlined the status to date and gaps, if any, in their progress.

SWAG members reviewed the 2015 and 2019 National Space Weather Strategy and Action Plans, the White Paper on the Implementation Status of the National Space Weather Strategy and Action Plan, and the Decadal Survey on Solar and Space Physics 2024-2033 white papers in developing their input to SWORM. One of the roles of SWAG is to provide a mechanism for broader community input to the Federal Government activities and planning. Therefore, SWAG held an open meeting with invited speakers and time for public input as part of their information gathering process. This meeting was held in a hybrid format on January 18-20, 2023, in Washington DC. An agenda for the meeting can be found in Appendix 3. The meeting was divided into seven panel discussions: Observational Data and Access (Ground-based and Airborne); Economic Assessments; Observational Data, Access, and Infrastructure in Space; Benchmarks, Metrics, and Scales; Data Infrastructure and Methods; Evolving Infrastructure Systems and Services; and Industry and Government Collaborations, Coordination, Outreach, and Communications on Space Weather. Each of the panels consisted of 3-5 speakers with ample time for committee discussion.

SWAG wishes to thank the individuals, both panelists and members of the public, who spoke at the January 2023 meeting. SWAG also wishes to thank SWORM members who attended and participated in the meeting. All the input was considered by SWAG and contributed to making this report better.

Use of This Document

This report is based on the input from the January meeting, SWAG's review of the 2015 and 2019 National Space Weather Strategies and Action Plans, the White Paper on the Implementation Status of the National Space Weather Strategy and Action Plan, and the Decadal Survey on Solar and Space Physics 2024-2033 white papers, and presentations and discussion from the January 2023 meeting. This report is organized around the seven panel discussions at the January meeting, and a chapter on overarching recommendations and one on additional key recommendations. Each chapter provides an overview of the topic, findings, and recommendations for SWORM as they move forward with updating and implementing the National Space Weather Strategy and Action Plan and PROSWIFT. In general, SWAG has not dealt with the prioritization of specific missions, sensors, or measurements.

Future SWAG Findings, Recommendations, and Updates

The findings and recommendations in this report are not yet informed by the results of the user-needs surveys SWAG is conducting pursuant to 51 USC 60601(d)(3). SWAG will develop additional findings and recommendations, as appropriate, based on the results of these surveys. SWAG will also review, or develop new findings and recommendations as appropriate, or at the request of Congress or SWORM.

Venue for Community Inputs: Congress established SWAG "for the purposes of receiving advice from the academic community, the commercial space weather sector, and space weather end users that informs the interests and work of [SWORM]" (51 USC 60601(d)(1)(A)). SWAG recognizes there are multiple avenues for the Federal Government to receive advice on space weather or associated phenomena. However, as the venue for community input on space weather, SWAG will continue to look for opportunities to receive input to inform Federal Government budgets for, policies on, and implementation of space weather activities. Additionally, SWAG will continue to collaborate, as appropriate, with other entities that provide space weather advice to help define their swim lanes.

National Resilience: The importance of reducing risk from space weather through resilience is further motivated by the increasing activity from the Sun during the current solar cycle (25), in contrast to the relative inactivity (from a historical perspective) during the last 16 years (i.e., solar minimum prior to and most of cycle 24). This report does not provide findings or recommendations on the mitigation of, response to, or recovery from space weather events.

Such activities are essential to ensuring resilience to space weather and reducing the risk to the Nation. SWAG will seek to evaluate these topics areas after the results of the user-needs surveys (pursuant to 51 USC 60601(d)(3)) are completed.

CHAPTER 2: Overarching Recommendations

Since the publication of the first National Space Weather Strategy, the national space weather enterprise has made noteworthy progress on improving awareness of space weather and its effects, understanding and forecasting space weather, and planning for space weather events. However, substantial investments are needed to build resilience and ensure space weather services can continue to improve and meet the growing and changing needs of the Nation. The findings and recommendations in this report, if implemented, will provide the funding, processes, support, and structure to foster transformative change across the national space weather enterprise.

Funding the Implementation of PROSWIFT

PROSWIFT authorizes many activities and delineates enduring roles and responsibilities for Federal departments and agencies. PROSWIFT identifies the need to include the capabilities and contributions from the academic and commercial sectors to successfully address space weather hazards. PROSWIFT, however, does not include appropriations or new funding to implement these activities and sustain these roles. Similarly, Executive Order 13744 and the National Space Weather Strategy and Action Plan identify a multitude of actions but do not provide funding. Without funding, the implementation of PROSWIFT and other space weather policies, furthering the national space weather enterprise, and building resilience to the effects of space weather will languish.

Finding 1. The Federal space weather enterprise is not sufficiently funded across all three legs (Federal Government and commercial and academic sectors) of the national space weather enterprise to implement PROSWIFT actions, perform and sustain the codified roles and responsibilities, or appropriately address the risk space weather poses to the Nation.

Recommendation (R.1.1.) Fund the Federal Space Weather Enterprise. Federal departments and agencies must be appropriately funded to implement the actions identified in PROSWIFT and ensure they can execute their statutorily identified roles. SWORM should work with Congress to identify new and sustained funding to address these shortfalls.

Enabling NOAA to Achieve Their Space Weather Priorities and Accomplish Their Space Weather Mission

NOAA identified space weather as one of six critical societal challenges in the Weather, Water, and Climate Strategy for FY 2023-2027. Applied and operational research in space weather modeling, operations, observations, data, forecasting, and products are key to achieving NOAA's desired five-year outcomes and beyond. To this end, NOAA has made strides to address the challenges of space weather through the creation of a space weather focused program office in National Environmental Satellite, Data, and Information Service (NESDIS) and the Space Weather Follow-On Lagrange-1 (SWFO-L1) mission. However, NOAA lacks a space weather program office focused on applied research and has historically not prioritized these types of activities, which are central to addressing space weather risks and are complementary to actions performed by the science focused agencies of SWORM. This has resulted in gaps in capability; a bottleneck in fielding operational capabilities for observations, modeling, and forecasting; and ultimately a greater risk to society.

Finding 2. NOAA is not properly structured to meet their statutory responsibilities codified in PROSWIFT (51 USC 60601(2)(A)) or their goal of addressing the critical societal challenge that space weather poses.

With a more appropriate structure, NOAA will be better able to achieve their goals and stated outcomes, improve progress in operational space weather activities, provide research to support operational responsibilities, and effectively accomplish their space weather roles and responsibilities. NOAA must prioritize, fund, and expand its ability to coordinate civilian space weather activities at a level commensurate with the critical societal challenge that space weather poses. In particular, SWAG has identified several persistent research-to-operations and operations-to-research (R2O2R) challenges, including funding for grants to improve readiness levels and maturity of models, operations-ready research data, transitioning data stewardship from research to operations, assisting in the transfer of operational data to the research community, and maintaining accessibility to long-term datasets.

R.2.1. Create and fund an applied research program office for space weather within NOAA to coordinate, facilitate, promote, and transition applied research across the national space weather enterprise. NOAA should establish and fund a program office within the NOAA Division of Oceanic and Atmospheric Research (OAR) focused on space weather research necessary to complement and support the space weather roles and missions of NOAA NWS and NESDIS, and to achieve the roles and responsibilities outlined in PROSWIFT, the Weather, Water, and Climate Strategy for FY 2023-2027, and other relevant policies. This new office should coordinate, facilitate, fund, and promote academic and private sector applied research across the national space weather enterprise.

R.2.2. Develop internal NOAA strategies to ensure agency-wide coordinated implementation of PROSWIFT and their national space weather policy responsibilities–both overall and within each service office. NOAA should develop an agency-wide strategy and coordinated strategies within each service or NOAA line office to ensure effective coordination and implementation of NOAA's PROSWIFT authorities and national space weather policy responsibilities and activities, including those identified in **R.2.1.**

R.2.3. Expand NOAA R2O2R functionality to enable the transition to full operations. There has been substantial progress by the agencies to develop and implement the R2O2R framework (Space Weather Research-to-Operations and Operations-to-Research Framework), including successes in establishing and implementing inter-agency partnerships on key space weather activities such as R2O grants and in-development operational and research missions (e.g., SWFO-L1 and Interstellar Mapping and Acceleration Probe (IMAP)). NOAA should expand the implementation of processes and capabilities important for a successful R2O2R function to address the identified R2O2R challenges and transitions–across the valley of death–to full operations, and include the academic and commercial sectors. Coordinating functions could reside in a space weather program office within NOAA's existing OAR Program Office, as identified in **R.2.1.**

Ensuring Coordination of Space Weather across the Federal Government

For more than a decade, OSTP has played a central role in coordinating the development and implementation of national space weather policy. The level of engagement for OSTP peaked in 2014-2018 when OSTP dedicated a full-time equivalent (FTE) with space weather expertise to the space weather portfolio. Since 2018, OSTP has not sufficiently supported the space weather portfolio–staffing it below ½ an FTE.

Finding 3. Sufficient staffing and prioritization of space weather by OSTP is necessary given PROSWIFT and their statutorily mandated role as coordinator for the "development and implementation of Federal Government activities conducted with respect to space weather to improve the ability of the United States to prepare for, avoid, mitigate, respond to, and recover from potentially devastating impacts of space weather" (51 USC 60601(b)). This will improve coordination and collaboration across agencies; maximize opportunities to take advantage of the exponential growth in space activities and budgets; and ensure the timely implementation of PROSWIFT, infrastructure policies, and national space weather policies that will reduce the risk of space weather to the Nation.

R.3.1. Ensure OSTP staffing and White House led prioritization and coordination across the national space weather enterprise. OSTP should place a higher priority on space weather in both staffing and policy documents (e.g., the annual Research and Development Priorities for the Budget). OSTP should sustain staffing at an FTE. This FTE should, preferably, have expertise in space weather and provide strong interagency leadership through the NSTC process–including developing a process to coordinate and align budget priorities for space weather. Additionally, OSTP should further coordinate space weather priorities across multiple White House councils and offices, including the National Security Council, National Space Council, and OMB to leverage and maximize the extent to which other national policy initiatives could help implement PROSWIFT and the National Space Weather Strategy and Action Plan.

A National Risk Register

Risks from threats and hazards like space weather are often not appropriately priced by the government or the private sector. This contributes to a lack of sufficient investment in resilience because the perceived financial consequences are not realized until the damage occurs. Myriad assessments, studies (e.g., FEMA's Natural Hazard Mitigation Saves Interim Report), and applications of cost-benefit analysis have demonstrated that preemptive investment in mitigation saves money (on average $3-6 for every $1 spent). To help inform the appropriate level of investment in space weather resilience, the risks from space weather should be quantified and put in the context of the broader risks that could affect the United States.

Finding 4. The Federal Government does not have a sufficient, overall, unified process to identify and quantify risks from threats and hazards, such as space weather, to the Nation. This likely results in funding and prioritization of space weather activities that is not commensurate with the level of risk posed to the Nation and society.

R.4.1. Consider space weather in the context of broader national risk. OMB should coordinate a process (e.g., a circular) to establish an enduring and regular interagency process for identifying and quantifying, in a comparable way, overall risks to the Nation from threats and hazards, and publish them in a public-facing report. This process could be modeled after the UK National Risk Register and its associated processes and include participation by industry and academia. The result of this process should be used to determine the overall risk from space weather relative to other national-level risks; and enable risk-informed prioritization of funding and activities to address the risk space weather poses.

Protecting Space Weather Sensors from Spectrum Interference

As societies around the globe become increasingly reliant on technology and economic activity in space, timely and accurate space weather products (e.g., forecasts, nowcasts, all clears, and situational awareness) become increasingly important. Technology systems are increasingly shifting to wireless applications, which broadcasts signals in the electromagnetic spectrum. In some cases, these technology applications can broadcast at frequencies that overlap with or are adjacent to the frequencies required by space weather sensors. Space weather sensors rely on specific characteristic frequencies over spectrum bandwidths that are fundamental, immutable characteristics of the nature of space weather, Earth, and solar phenomena. These sensors, which are located on the ground, in the air, and in space, can be vulnerable to noise and inference from technology systems that broadcast electromagnetic signals in the same or at adjacent frequencies. Such interference can disrupt the sensors' abilities to provide usable and accurate data, which could stop the Nation's or world's ability to forecast and provide situational awareness for space weather.

Finding 5. Space weather sensors are vulnerable to and potentially at risk of spectrum interference from electromagnetic emissions (e.g., radio frequency) originating from technology systems (e.g., 5G applications). Emissions at frequencies similar to those used by space weather sensors could disrupt the sensors' abilities to provide key data necessary to inform space weather products, forecasts, nowcasts, and situational awareness. Appropriate domestic and international protections should be given to space weather sensors parallel to those given to terrestrial weather sensors.

R.5.1. Protect space weather sensors from spectrum interference. SWORM should coordinate with relevant agencies, including the National Telecommunications and Information Administration, to establish domestic and global protections (e.g., United Nations) for space weather sensors akin to terrestrial weather sensors.

CHAPTER 3: Ground-Based and Airborne Sensors and Networks

Ground-based and airborne sensor networks provide cost-effective and reliable data for space weather operations. Many of these sensors are used for fundamental research that leads to improvements in space weather models and support real-time situational awareness of conditions on the ground, in the air, and in the near-Earth space environment. Sensors such as magnetometers, neutron monitors, incoherent scatter radars, airborne radiation monitoring, scintillation monitors, all-sky imagers and ionosondes have high heritage, and can provide reliable data streams. At or near the surface of Earth, such assets are easily accessed for upgrade or maintenance, which allows for longer-term missions that can be improved and upgraded over time. However, because of the fundamental research nature of most sensor networks, there has not been a viable path for these instruments to be supported, maintained, and funded for long-term operational applications. Additionally, consideration should be given to determine the optimal location (e.g., geographical, or orbit) and domain (e.g., ground, air, or space) of these sensors and networks.

Finding 6. A fundamental change is needed in the way ground-based and airborne sensors and networks are prioritized, supported, and maintained, including those operated by academic and commercial sectors, to enable operational products and services.

R.6.1. Assess and publish the prioritization of ground-based and airborne sensors needed for current and future space weather products. SWORM should develop, publish, and regularly update a ranked list of ground-based and airborne observations that would contribute the most significant improvements to space weather products and situational awareness. This list should consider government, commercial, and academic sensors and networks that are operational or can be transitioned to operational in the future. The White Paper on the Implementation Status of the National Space Weather Strategy and Action Plan refers to a “baseline report of the space- and ground-based observations necessary to satisfy space weather forecasting requirements'' (Section 2.1). If this report contains a ranked list of ground-based observations, its public release may partially satisfy this recommendation.

R.6.2. Provide long-term support for operational ground-based and airborne sensors and networks. NOAA, as the civil operational space weather agency, pursuant to 51 USC 60601(2)(A), is responsible for maintaining “ground-based… assets to provide observations needed for space weather forecasting, prediction, and warnings” and therefore should provide long-term support for ground-based and airborne sensors and networks, including, but not limited to the priority sensors and networks identified in **R.6.1.** As part of this process, NOAA should determine how to best deploy such sensors to maximize the current and future benefit to operational space weather services. NOAA should seek additional funding to ensure their ability to perform this statutory role. This should exclude the U.S. Geological Survey (USGS) magnetic observatories, which should continue to be maintained by USGS.

R.6.3. Fund the transition of NSF research sensors and networks to operations. The National Science Foundation (NSF) has identified and supported the development and transition from research to operations novel ground-based sensors and networks (e.g., the Global Oscillation Network Group (GONG observatories)). Other sensors may now be candidates for the transition to operational use. NOAA should work with NSF to develop and implement a plan to identify and transition candidate sensors to operational status and transfer long-term support obligations in accordance with **R.6.1.** and **R.6.2.** and where such ground-based sensors or networks make operational and financial sense compared to other domains (e.g., space-base).

R.6.4. Coordinate support for ground-based and airborne sensors and networks that are essential to space-based missions. For space-based missions that depend on ground-based sensors or networks (e.g., THEMIS--Time History of Events and Macroscale Interactions during Substorms Mission and the All-Sky Imagers; Geospace Dynamics Constellation (GDC) and the Incoherent Scatter Radars, Imagers, etc.), NASA should coordinate with NSF to provide sufficient support for the maintenance or development of the ground-based elements that are essential for the success of the mission. This support should ensure that timelines are aligned, and budgets are sufficient to cover both the space and ground segments. This may include NASA providing financial support to ensure the timely success of the ground segments.

Finding 7. NOAA has successfully used Cooperative Research and Development Agreements (CRADAs) to foster collaboration between government and non-government entities to evaluate and improve the use and availability of operational data from ground-based sensors.

R.7.1. Expand the use of CRADAs to improve collaboration across the academic and commercial sectors. NOAA should use CRADAs more widely to further partner with the academic and commercial sectors to evaluate the ability of data from ground-based or airborne sensors and networks to improve space weather products, forecasts, predictions, and warnings.

Finding 8. While the completed magnetotelluric (MT) surveys of the United States have contributed a high value for science, the next most valuable investment and step is supporting real-time ground-based, operational magnetometers. Real-time specifications of the geo-electric field in the contiguous United States currently rely solely on data streams from six USGS magnetic observatories. This sparse distribution results in coverage gaps greater than 1,000 km and includes high-hazard regions such as Minnesota and New England. With the expected near-term increase in geomagnetic activity and geoelectric field hazard to the power grid during solar maximum, it is a high priority to quickly augment Federal forecasting capabilities by leveraging existing non-government magnetic field sensors that can be put into operations in both of these high-hazard regions.

R.8.1. Prioritize the addition of underutilized, existing real-time magnetometer data streams over new MT survey campaigns. NOAA should prioritize real-time data streams, transition high-priority existing ground-based magnetometer networks into operations and provide long-term support in accordance with **R.6.2.** These data streams can also be used to inform future decisions regarding the MT surveys.

CHAPTER 4: In-Space Architectures and Space-Based Observations

Maintaining U.S. leadership requires providing space weather services to operators in regions of space for commercial, economic, regulatory, exploration, and security activities as well as continuing the fundamental space weather research that leads to improved predictive and modeling capabilities. The Nation's plans for in-space architectures and space-based observations must be responsive to changes in how space is utilized. Funding in support of space weather operations and research should be prioritized by the agencies and at the scale required to meet their space weather objectives and overall interest in space activities.

Finding 9. Space weather services are necessary to support robotic and human activities in space. Space weather services include the data, data products, forecasts, nowcasts, warnings, benchmarks, catalogs, models and other information or tools that affected communities use to prepare for or respond to space weather events. These services need to expand from a near-Earth emphasis to include farther from Earth (e.g., medium-Earth orbit (MEO), geostationary Earth orbit (GEO), and geostationary transfer orbit (GTO)), and beyond Earth (i.e., cis-Lunar and eventually Martian space). Providing space weather services in these regions is of growing importance as U.S. defense, commercial, economic, and human exploration activities have increased or are planned in these regions. The current National Space Weather Strategy and Action plan does not adequately reflect the national need in these regions. Expanding the Strategy and Action Plan to include environments relevant to human exploration is aligned with Space Policy Directive 1 and PROSWIFT (51 USC 60601(a)(1)(E)). This will eventually require expanded operational space weather programs at NOAA.

R.9.1. Revise the National Space Weather Strategy and Action Plan to broaden service coverage of additional space environments. SWORM should update the National Space Weather Strategy and Action Plan to include space weather services for near-Earth (LEO), farther from Earth and cis-Lunar and Martian environments.

R.9.2. Provide and fund critical operational space weather services beyond near-Earth. For near-Earth, farther from Earth, cis-Lunar and eventually Martian space, NOAA should update and expand the critical (baseline) operational space weather services needed for robotic or human activities in each environment and develop a plan to provide continuous data. Such services should be developed and deployed in addition to the existing and growing space weather services in the near-Earth environment. The need for increased solar and heliospheric coverage to provide forecasts for locations such as Mars, and improve forecasts in the other priority regions, should be evaluated and addressed. NOAA should seek increased funding and partnerships (e.g., Department of Defense (DOD), NASA, commercial, or international partners) to support an expanded in-space architecture to meet growing national needs in these regions. NOAA should seek additional funding to provide expanded space weather services to meet evolving national needs beyond low-earth orbit.

Finding 10. Space weather phenomena affect technological systems on a local and global scale. The NASA Heliophysics Division has greatly expanded the Heliophysics System Observatory (HSO). However, HSO could be further improved through a more coordinated and optimized approach to overall system-science development. Furthermore, additional basic research is still needed to understand the underlying physics to improve and expand predictions and forecasts. The space weather research community has identified the need for in-space observations which connect systems; address mesoscale or global processes; access new (unexploited) vantage points; combine interdisciplinary approaches; integrate multi-point measurements; and fill observation gaps throughout the solar system.

R.10.1. Fund NASA missions that advance fundamental science to support space weather research. NASA should seek increased funding to support coordinated and integrated space weather research missions that address fundamental science. Funding in support of space weather research missions should be commensurate with the risk space weather events pose.

R.10.2. Use a coordinated approach to develop and deploy missions that advance fundamental science supporting space weather. Taking a systematic approach to in-space architecture development and deployment is essential to enable research across phenomenological scales. To facilitate systems-level research goals NASA should coordinate development of missions which address space weather science. NASA could employ simulation tools (e.g., Observing System Simulation Experiments) and deploy missions in a strategic order to provide opportunities for coordinated measurements between missions.

R.10.3. Establish O2R traceability in the NASA mission formulation process. Formalize the process for DOD and NOAA to provide O2R inputs into NASA's space weather research mission formulation by providing a means for traceability in the research mission formulation process. For example, consider developing an Operational Traceability Matrix (OTM) to complement a Science Traceability Matrix (STM) and Mission Traceability Matrix (MTM). The OTM could be used as a centralized tool that tracks technical mission drivers (e.g., continuous data links and availability), interface requirements (e.g., data routing and standardization) and functional development (e.g., model testing and deployment) to implement an operational space weather capability on a research mission.

R.10.4. Develop a prioritization of space-based sensors to enhance space weather products. SWORM should develop a prioritized list of space-based observations that would contribute the most significant improvements to space weather services and situational awareness and make it publicly available. SWORM should utilize the science and user community documents (e.g., Solar and Space Physics: A Science for a Technological Society, SWAG user need assessment, Space Environment Engineering and Science Applications Workshop (SEESAW) and Space Weather Gap Analysis Report) as input. This list should consider contributions across the national space weather enterprise. Additionally, consideration should be given to determine the optimal location (e.g., geographical, or orbit) and domain (e.g., ground, air, or space) of these sensors and networks.

Finding 11. Developers and operators of space systems require more consistent space weather data in high-interest regions (such as near-Earth, beyond near-Earth, cis-Lunar, Mars, and along the Sun-Earth line) and need improved coverage throughout the solar system.

R.11.1. Opportunistically deploy more space weather sensors. NOAA, NASA, and DOD should pursue inter-divisional, inter-agency, international, and commercial partnerships to manifest prioritized (**R.10.4.**) space weather sensors on as many missions, and in as many unique orbits, as possible.

R.11.2. Fly space weather particle sensors on every U.S. Government procured space vehicle. SWORM, working with OMB, should modify the Federal acquisition regulations (e.g., the Federal Acquisition Regulations and Defense Federal Acquisition Regulations) to ensure that space weather particle sensors manifest and fly on all U.S. Government procured observatories, platforms, and space vehicles and make the data publicly available.

Finding 12. Space weather forecasts depend on specific observational data. The measurements or other capabilities which enable these data must be sustained for the continuity of forecasts.

R.12.1. Sustain resilient approaches to ensure continuity of in-space, operational space weather observations. NOAA is moving forward with the development of Space Weather Next and should continue planning a resilient space weather architecture that includes on-orbit back-up to support space weather forecasts in the event that critical measurements are lost.

CHAPTER 5: Data and Computing Infrastructure for Space Weather Operations

There has been an explosive growth in data availability, and a rapid advancement of new models that include advanced artificial intelligence (AI) and machine learning (ML) algorithms. This new data-forward domain presents opportunities and challenges for space weather. However, technology is evolving more rapidly than the current pace of space weather infrastructure development for operations. Preparing for, and evaluating the utility of, these powerful technologies should be a high priority for operational space weather.

Users of space weather data report that the data they need to support in-space mission design or development, routine operations, and model development is difficult to find, does not exist online, or in useful formats. Satellite operators report that they use self-compiled lists of disjointed online resources to access the information they require, including an inability to find a baseline or consensus neutral atmosphere in which to propagate their orbits for valid comparisons with other users. For time-critical situations, such as anomaly resolution during flight, data access issues can delay the analysis needed to resume nominal operations.

Finding 13. The infrastructure and workforce to support new data and models are not being developed at a pace that meets the needs of emerging technologies and new data streams.

R.13.1. Fund, formalize, and expand the NOAA space weather prediction testbed.
NOAA's aviation testbed exercise was a successful starting point for the NOAA space weather prediction testbed function. As the space weather prediction testbed matures, it should provide a conceptual framework and both a virtual and physical space to foster collaboration between research and operations to test and evaluate emerging technologies and science for NOAA's Space Weather Prediction Center (SWPC) operations. The testbed should be funded at a level to support transition of new data and models necessary for space weather operations in a timely manner. The testbed should involve, and train as appropriate, partners in the academic and commercial sectors. Its scope should expand to include the maintenance of NOAA databases that are used by the community to ensure continuity and robustness, and the creation and implementation of standards for space weather operations data and event lists that promote ease of use across communities.

The NOAA testbed should be appropriately funded to (i) ensure that benchmarks can be referenced by end users in performing assessments; (ii) incorporate end-user expertise and research in ensuring that benchmarks accurately reflect effects of space weather on the system technology; and (iii) establish mechanisms such as CRADAs, Memoranda of Understanding (MOUs), other agreements, and even roundtable discussions to obtain end-user information that can support sustained, long-term improvement of space weather benchmarks. This should be done in coordination with **R.16.1.**

R.13.2. Improve access to space weather data. NOAA should ensure and maintain a relevant and coordinated online portal that compiles space weather data from across the enterprise.

R.13.3. Improve interagency coordination of models and data. NOAA and the Department of Air Force should improve coordination and collaboration on space weather models and data sources and develop a process for establishing a baseline upper atmosphere that can be used by civil and defense organizations.

R.13.4. Promote and prepare for the use of AI/ML algorithms as a complement to traditional empirical and physics-based models. In recent years NSF and NASA have supported development of AI/ML laying the groundwork for interdisciplinary use of these new tools and techniques. Additionally, a significant amount of the growth in AI/ML algorithms has been achieved by the commercial sector. NOAA, NASA, NSF, and DOD should coordinate and engage in partnerships with subject matter experts, including the commercial sector, to rapidly advance space weather capabilities in these areas.

R.13.5. Continue to identify and release novel and underutilized data sets that improve space weather products. Several successful data releases by industry and DOD are improving data access for the space weather enterprise. For example, the White House successfully coordinated the release of underutilized data sets relevant to space weather (e.g., the vertical Total Electron Content (vTEC) dataset). Similarly, the Federal Energy Regulatory Commission (FERC) directed the electric power industry to collect and make industry geomagnetically-induced current measurements and magnetometer data publicly available to improve the collective understanding of space weather risks. Access to such databases (including satellite anomalies) should be expanded to allow for use by academic and commercial researchers. DOD, the Department of Energy (DOE), NASA, and NOAA should develop a process to assess which datasets might be candidates for utilization by the space weather enterprise and determine a release schedule for such data.

R.13.6. Promote career pathways for interdisciplinary technologists supporting the space weather enterprise. SWORM should promote the development of career pathways for interdisciplinary technologists, including data scientists, research software engineers, and instrument scientists. These individuals may not qualify for career advancement using traditional metrics such as their publication records, but they play a critical role in designing, maintaining, and efficiently using space weather cyber-infrastructure. Conferences, training programs, educational programs, and scholarships targeting the needs of the next generation of space weather researchers (e.g., AI/ML, cloud computing, data mining, and interdisciplinary heliophysics science) should be expanded.

CHAPTER 6: Improving Benchmarks, Metrics, and Scales for Space Weather End-Users

Space weather can cause significant disruption to many facets of society. Space weather end-users across all industries need benchmarks, metrics, and scales to more fully understand and mitigate the effects of space weather on operations and services. For example, aviation, which is integral to global commerce, can be hindered by space weather which can interrupt radio communication, make navigation unreliable, and affect human health. The power industry, which provides the lifeblood for society, can experience equipment failure from ground induced current surges leading to widespread power disruption. LEO satellites, which are becoming the next waypoint for global commerce, have orbits that can be modified by highly variable atmosphere drag which increase collision uncertainties. All these effects are directly attributable to space weather.

The NOAA space weather scales have provided the worldwide standard, decades-long legacy of improved space weather understanding for end-users. NOAA scales have provided a basis for selecting the safest operating procedure for given space weather conditions but may now be too generalized given the increasingly complex operating environment. To effectively operate in an ever-changing environment there is a need to evolve the accuracy and specificity of these scales for individual industries or applications. In unison with needed enhancements of scales, there is also a need for education at a level that matches the complexity of space weather and how it affects technology systems.

Finding 14. The National Space Weather Action Plan (2015) established benchmarks, which provide points of reference, for induced geo-electric fields, ionizing radiation, ionospheric disturbances, solar radio bursts, and upper atmosphere expansion. Continued refinement of space weather benchmarks is necessary to bridge government, academic, and industry expertise, which was started by the next step space weather benchmarks process.

R.14.1. Coordinate benchmark development or improvement with industry. For industries that have mature benchmarks, SWORM, in coordination with industry, should reconcile government and industry benchmarks to ensure the latest research and knowledge from industry and the space weather enterprise is applied and can be expressed in terms and parameters that are applicable to end users. For industries that do not have mature benchmarks, SWORM should involve industry in the development of new benchmarks. In particular, government and industry coordinated benchmarks for geoelectric fields should be a high priority for the reconciliation process based on their high level of maturity. SWORM should support the development of benchmarks for both extreme and less intense events. Sector risk management agencies and appropriate regulatory agencies, such as the Department of

Homeland Security (DHS), DOE, Department of Transportation (DOT), the Federal Aviation Administration (FAA), DOD, FERC, and the Nuclear Regulatory Commission (NRC) should take lead roles in coordinating these improvements.

R.14.2. Promote industry participation in workshops and meetings to inform the mitigation of space weather hazards. SWORM has effectively engaged industry representatives, including those in energy, space flight, navigation, communication, and aviation, to create industry-level initiatives for informing the mitigation of space weather hazards through workshops and meetings. Sector risk management agencies and relevant regulatory agencies (including DHS, DOD, DOE, DOT, FAA, FERC, and NRC) should support the continuation of these activities through funding or other mechanisms to support industry participation.

R.14.3. Use multiple approaches to validate benchmarks. SWORM, led by the relevant sector risk management agencies and regulatory agencies (including DHS, DOD, DOE, DOT, FAA, FERC, and NRC), should use validation assessments to improve space weather benchmarks for assessing effects on technology. Validations should make use of empirical, statistical, physics-based, machine-learning, data assimilative, and ensemble models as well as measurements from all physically relevant temporal and spatial domains in the benchmark development processes.

Finding 15. Metrics supporting long-term characterization of space weather conditions, and scales identifying levels of space weather activity, require improvements to support an increasingly diverse user landscape. Industry-specific indices should be prioritized for development to address individual needs of the user.

R.15.1. Identify and prioritize the development of key space weather metrics. SWORM agencies, led by the relevant sector risk management agencies and regulatory agencies (including DHS, DOD, DOE, DOT, FAA, FERC, and NRC), should identify and prioritize the development of key space weather metrics. These should include the solar, magnetospheric, thermospheric, and ionospheric domains to ensure long-term, consistent characterization of space weather effects and environmental baselines. Industry-specific scales should be identified, based on user needs (including the results of SWAG user-needs surveys), and used to support the prioritization of new infrastructure, sensors, instruments, and models.

R.15.2. Update and expand NOAA space weather scales. NOAA scales should be updated and expanded based on the metrics identified in **R.15.1.** and include spatial and temporal specificity relevant to user operational activities. And move the application of scales beyond strict classification levels of space weather events towards forecasting impacts and specifying how space weather will differentially affect systems, industries, sectors, or regions–akin to the evolution of impact-based warnings and decision support services and scales used for other terrestrial weather hazards, e.g., hurricanes.

R.15.3. Maintain historical space weather indices. The use of global proxies and indices are important for historical and longitudinal studies as well as for the continued operation of legacy models that depend on them. As new industry-specific proxies and indices are developed, NOAA should maintain legacy proxies and indices to ensure continuity of operations and for space weather research.

CHAPTER 7: Space Weather Risk to Evolving Infrastructure Systems and Services

Infrastructure systems and services are rapidly evolving as new technology is integrated (e.g., the digitization and transition to more distributed generation across the electric power grid), and new infrastructure systems are deployed to meet novel demands for capabilities (e.g., proliferated communications systems in LEO and space traffic coordination). The evolution of the elements or characteristics of these infrastructure systems, and interdependencies with other infrastructure systems change its vulnerability to space weather.

As infrastructure systems evolve, changes in the characteristics of infrastructure systems or interdependencies among other infrastructure systems can change the vulnerability to space weather. Infrastructure evolution also changes the end-user's capabilities for responding to space weather risks, which alters the products or services needed. Other changes arise from evolution in priorities for protecting and strengthening infrastructure systems to align with growing national priorities. The space weather enterprise must keep pace with the evolution of infrastructure.

Finding 16. There is a need for regular collaboration with infrastructure owners, operators, and end-users to incorporate the needs of evolving infrastructure. Infrastructure sectors are rapidly evolving, integrating new capabilities and incorporating activities to identify and address risk from space weather events. For example, the electric power grid is transforming, while at the same time grid owners and operators are implementing reliability standards to improve resilience to space weather. This is changing the electric power industry's need for space weather products, which may require increased granularity, lead-time, and specificity.

R.16.1. Develop an enduring process to understand evolving infrastructure needs. SWORM agencies, led by DHS, should develop an enduring process to understand the evolving needs and requirements of industry for space weather products, benchmarks, scales, and metrics as part of the process recommended in **R.15.1**. This should start with incorporating the results of the SWAG user-needs surveys to inform risk assessment needs and efforts to identify and build resilience across those critical infrastructure systems, assets, and technologies at greatest risk to space weather.

R.16.2. Leverage industry assessments and applications of MT data and geomagnetically induced current (GIC) data to improve Earth conductivity models and GIC assessment tools. SWORM, led by DOE and FERC, and the electric power industry should collaborate to understand, advance, and improve Earth conductivity models, including MT survey data, which are important for accurate vulnerability assessments and mitigation planning. SWORM, in its

White Paper on the Implementation Status of the National Space Weather Strategy and Action Plan, contends that previous power grid vulnerability assessments may not have considered the full 3D effects of earth conductivity structures and that USGS efforts are likely the first attempts to appropriately leverage new MT data. However, research performed by and in support of the electric power industry has applied MT data to improve Earth conductivity models used by the industry in the existing, state-of-the-art assessment and mitigation tools. The electric power industry and a broad research community should be involved in efforts to appropriately leverage MT data and geomagnetically induced current data for accurate Earth conductivity models and effective assessment tool development.

Finding 17. Activities to reduce space weather risks and enhance resilience are progressing in varying degrees across infrastructure sectors. An increased focus is needed on infrastructure sectors that may be lagging. The electric power subsector and aviation subsector have determined that space weather is a sufficient threat to the reliability of their infrastructure services and have taken action through regulatory and requirements processes to assess and address the effects of space weather on their systems. Other critical infrastructure sectors or subsectors do not yet have similarly mature and broad approaches for reducing risk and promoting resilience to the effects of space weather. This drives uncertainty in understanding the vulnerability space weather might have on that sector and to the Nation overall.

R.17.1. Promote the development of vulnerability assessments by sector owners and operators. SWORM, led by DHS with participation from sector risk management agencies, should clarify the focus of Objective 1.2 in the 2019 National Space Weather Strategy and Action Plan to encourage and enable the development of industry-led vulnerability assessments, plans, processes, and procedures to reduce risk to space weather events.

R.17.2. Prioritize addressing space weather risks in sectors other than electric power and aviation. SWORM should prioritize completing actions for key sectors that currently do not have sector-wide processes to assess and address the risks of space weather, including telecommunications and space traffic coordination.

R.17.3. Address interdependencies of and cascading risks to critical infrastructure. SWORM agencies (including DOE, DHS, DOT, FAA, FERC, NRC, and NOAA) should continue to engage the electric power subsector and aviation subsector to incorporate evolving infrastructure needs for space weather products and address the challenges associated with cascading risks across interdependent sectors and subsectors.

CHAPTER 8: Economic Assessments on the Cost of Space Weather and the Value of Forecasting and Mitigation

Effective economic assessments of the space weather enterprise are important tools to determine the potential costs to society of space weather events and the cost averted by addressing the risks through forecasting and mitigation. Without these assessments, risk cannot be quantified and the value proposition for investments in space weather research, observations, forecasting, and mitigation cannot be determined. These assessments are challenging for myriad reasons, including data scarcity, the proprietary nature of effects, and cause and effect attributions. Additionally, space weather may also not be sufficiently well known to communities studying hazards and risks or to those conducting economic assessments.

Finding 18. Economic assessments are important for informing how the risk of space weather should be addressed and for prioritizing funding for observations, models, mitigation measures, and insurance products. They are the basis for determining societal benefit.

R.18.1. Quantify the societal benefits for addressing risk from space weather by performing national-level and industry-wide economic assessments. NOAA, in collaboration with the Department of Commerce (DOC) and the sector risk management agencies, should quantify the societal benefits of space weather observations, forecasting, and mitigation, including cost avoidance by sector, service, or infrastructure type.

R.18.2. Develop and curate data necessary for effective economic assessments. Economic assessments should cover both extreme events and more frequent, and lower-intensity events. DOC should evaluate the use of additional proxies and analogs (e.g., other hazards or similar events) to inform economic assessments of the cost of space weather. These assessments should include benchmarks, metrics, and scales (existing or under development), which will enhance the assessment specificity. Further, DOC should identify key missing data (e.g., historical, forensic, or forward looking) and implement pathways to obtain said data.

R.18.3. Broaden the scope of economic assessments. DOC should broaden economic assessments to include operations, data and contracts, and full costs accounting associated with surge response activities (e.g., engaging emergency response teams, program managers, operations teams, etc., within or across governments and private sectors) to deal with space weather events. Potential costs of false negatives and false positives should be included. Given the growth in the space economy, DOC should prioritize economic assessments of space activities that could be affected during space weather events. Forensic assessment teams should be developed to capture historical examples and develop cost assessments from realworld incidents of space weather affecting infrastructure systems. DOC should undertake economic assessments of the consequences of space weather that go beyond the worst case to include more frequent, lower intensity events. This may require the development of new benchmarks and scales, as identified in **Findings 14 and 15**, to sufficiently describe the events and consequences of concern. These may be linked to design lifetimes for infrastructure of concern. Lastly, DOC and NOAA should assess the cost to mitigate space weather in addition to the cost of consequences.

R.18.4. Engage additional stakeholders for economic assessments. DOC, in coordination with the sector risk management agencies and relevant regulatory agencies (e.g., DHS, DOD, DOE, DOT, FAA, FERC, NRC, and Treasury), should engage owners and operators, risk assessors, and insurers to identify thresholds of operational concern that are important to inform economic assessments. DOC should encourage more community activity around economic assessments of space weather consequences–fostering increased collaboration among science, engineering, and economic analysis communities.

CHAPTER 9: Promote Focused and Continued Engagement across Industry and Government Space Weather Stakeholders

One of the many challenges to improving the Nation's ability to address the consequences of space weather on infrastructure and economy is the efficient and comprehensive communication and engagement both within and across government agencies and industry stakeholders. The lack of a single Federal entity focused on managing the Federal space weather enterprise has resulted in a piecemeal approach. As outlined in PROSWIFT, Executive Order 13744, and the National Space Weather Strategies: space weather requires coordination, collaboration, and cooperation across many Federal departments and agencies. In addition to improved communication, transparency related to civil and governmental research and operational consequences is also needed. While great progress has been made with the engagement of specific industries (e.g., power grid, aviation), it is imperative that similar levels of engagement be achieved with less visible stakeholders.

Finding 19. A key piece of national space weather policy is the need to establish and continue coordination of space weather research, awareness, information and products, and ways to address its effects among government, academic, and industry stakeholders.

R.19.1. Enhance distribution of space weather products. SWORM should investigate and support the creation of a focused center (e.g., an Information Sharing and Analysis Center (ISAC) watch center) dedicated to the coordination and dissemination of space weather information, products, and forecasts and serve as a venue for industry feedback. To improve knowledge sharing, SWORM should facilitate a virtual clearinghouse that captures completed space weather-related Phase II Small Business Innovations Research (SBIR) activities. This would facilitate commercialization, re-use, and Phase III implementation.

R.19.2. SWORM should increase transparency by ensuring the publication of foundational documents, studies, and policies. SWAG encourages SWORM and OSTP to make as much of its work public as possible. For example, making the Implementation Plan and Science and Technology Policy Institute reports public.

Finding 20. The lack of extant MOUs or memoranda of agreement (MOAs) can be an impediment to cooperation and interaction between and among Federal departments and agencies.

R.20.1. Develop standing MOUs or MOAs across and between all SWORM agencies. Improve coordination efficiency and data sharing by establishing MOUs or MOAs across and between all SWORM departments and agencies to enable efficient coordination and collaboration. For example, an important benefit will be establishing the ability to regularly share reporting of space traffic coordination advances and obstacles, as the field rapidly advances.

Finding 21. There is a need for tabletop exercises to help organize and outline the steps that might need to be taken during a space weather event. By discussing the scenario and simulating responses in advance, space weather stakeholders and the communities affected can identify challenges and opportunities to improve space weather resilience, messaging, emergency management, and preparedness.

R.21.1. Develop and implement broader participation in tabletop exercises. SWORM should develop and implement space weather tabletop exercises that involve combinations of Federal agencies, local and regional governments, international partners, commercial stakeholders, and academia. There is a need to identify communication, response, and mitigation plan gaps at the Federal, local, and stakeholder levels during space weather events. These exercises should include international partners for globally coordinated messaging and appropriate responses.

CHAPTER 10: Other Key Findings and Recommendations

In addition to the previous 21 findings, SWAG has identified other key findings and recommendations that do not fit neatly into a single chapter or are not sufficiently overarching to be in the first chapter. Nevertheless, these findings and recommendations are important and, once implemented, will make significant contributions to advancing the national space weather enterprise.

Assessing and Addressing National Security Risks from Space Weather

Space weather poses a unique risk to the execution and performance of the U.S. national security mission. National security is highly sensitive, broad, and complex; primarily performed by the Federal Government; and reliant on myriad technologies and capabilities. Operations in rugged, covert, and contested environments can compound the effects of space weather on the national security mission.

Finding 22. The national security mission is broadly and uniquely exposed to space weather risks. Such risks warrant assessment(s) unique to mission circumstances.

R.22.1. Develop a national security annex or policy on space weather. National security stakeholders of SWORM should develop a national security focused annex, or similar product. The product(s) should: (1) identify key missions, platforms, and technologies, both fielded and developing, which should be targeted for space weather risk assessments; (2) broaden awareness and messaging of space weather products and capabilities of the Department of the Air Force (military lead) and the Space Weather Prediction Center (civil lead); (3) identify needs, gaps, and opportunities for space weather products, forecasting, and techniques and approaches appropriate to address the risk of space weather to assure national security across all domains; (4) include space weather risks in procurement requirements, where appropriate; and (5) review workforce needs and space weather products for assuring the national security mission.

Promoting Public Awareness and Education for Space Weather

Space weather is a potential risk to all organizations and facets of society in the United States. Unlike terrestrial weather hazards, the harmful characteristics of space weather do not often have a direct visible manifestation, unlike tornadoes or wildfires. However, space weather has the potential to negatively and simultaneously affect the entire continent of North America or even an entire hemisphere.

Finding 23. SWORM must broaden and augment community and stakeholder engagement on space weather.

R.23.1. Improve public awareness, education, and engagement regarding space weather application effects. SWORM should continue to improve public awareness and education around space weather—across governments, the public and private sectors, and throughout society. Through developing, supporting, and promoting outreach events, SWORM should set goals to improve societal knowledge on what space weather is, how it could affect citizens, where one looks to receive space weather information and products, and how one interprets the message.

Critical Need for Thermospheric Density Specification to Aid Operational Systems

The global economy and national security are more tightly linked to variations in the LEO environment than ever before. Proliferations of space vehicles in LEO are increasing to meet the demand for global communications, internet connectivity, and LEO-driven imagery that provide critical information for civil, commercial, and defense applications. The number of objects in LEO is set to triple over the next two years. Growth in the number of LEO objects directly increases the probability of unintentional collisions between objects due to accumulating space debris and autonomous spacecraft maneuvers. Environmental characteristics of the thermosphere are directly affected by space weather events. The situation is compounded by uncertainties in thermospheric models for the very low earth orbit (VLEO) and LEO environments.

Finding 24. Support for coordinated applied research of the thermosphere is necessary to improve space traffic coordination and avoid the negative consequences of space weather on the growing number and importance of space assets in LEO.

R.24.1. Support coordinated applied research for the thermosphere (above 100 km altitude) which is critical for space traffic coordination. NOAA Office of Space Commerce (OSC) should promote and develop LEO density, orbital trajectory and collision probability, and re-entry window models that enable predictions through active engagements across the national space weather enterprise. This will require coordination across NOAA OSC, NWS, NESDIS, and NASA Office of Conjunction Risk Assessment, as well as academic and commercial sectors that are active in this area.

R.24.2. Support coordinated R2O2R workshops and testbed activities for space traffic coordination. NOAA OSC in coordination with NASA Heliophysics Division should support R2O2R activities that will aid in quantifying the variability and uncertainty in modeled global and regional thermospheric density and winds in the broader context of space traffic coordination, with a goal of reducing this uncertainty.

R.24.3. Support and encourage new processes for the incorporation of data and observations to characterize the thermosphere (above 100 km altitude) environment. NOAA OSC should devise a process to help ensure the safety and success of entities operating on the ground, in air, and in space by encouraging and supporting their contribution of thermospheric temperature, density, and wind observations for model ingest similar to what airlines do for terrestrial weather over a range of relevant timescales (e.g., hours to years).

Enhancing Global Engagement

The global risk from space weather is evolving as the world becomes more reliant on technology and space-based infrastructure and drives towards increased economic activities in space near Earth and beyond. Addressing this evolving risk requires new, additional, enhanced, and specific space weather products and information. These products require new and additional observations, data, and models–particularly for activities beyond Earth in cis-Lunar space and around Mars and for new applications such as space traffic coordination. Addressing the growing need for space weather products requires fielding a multitude of new platforms and missions.

The United States has historically been a primary developer and funder of observations and forecasting capabilities for space weather. However, it may no longer be tenable for the United States to continue to be the primary funder for new missions while ensuring continuity of existing critical observations. The growing global demand for space weather must include a commensurate global contribution to the space weather enterprise. Furthermore, the messaging and actions taken in response to a space weather forecast or event must be coordinated. This presents an opportunity to deepen existing international relationships by adding the collaboration and cooperation on space weather and forge new relationships.

Finding 25. The U.S. Federal Government should seek more opportunities to collaborate, coordinate, and co-fund observations, forecasts, and capabilities with partner and allied nations around the world, broadening international engagement, collaboration, and coordination to meet the growing need for space weather products.

R.25.1. Foster and lead a global space weather enterprise. The State Department (State), working through the appropriate international organization (e.g., the United Nations) should foster a global process for the prioritization, coordination, collaboration, and joint funding of space weather missions, activities, data acquisition, scales, benchmarks, and products.

R.25.2. Promote Five-Eyes space weather collaborations. State should lead the establishment of an enduring Five-Eyes (i.e., United States, United Kingdom, Canada, Australia, and New Zealand) based space weather collaboration to address national security related issues that may affect the United States and its closest allies.

R.25.3. Formalize bi-lateral or multilateral agreements to support coordinated messaging, mutual resilience, and to further the global space weather enterprise. State should formalize bi-lateral and multilateral agreements or partnerships to improve space weather forecasting capabilities, products, and messaging. Space weather is a global phenomenon that has local, regional, and global effects. Thus, it is essential to establish a globally coordinated strategy, mission, and infrastructure which requires engagement of international partners to distribute both infrastructure material and cost–among government and non-government stakeholders.

R.25.4. Participate in and leverage the international standards development relevant to space environment and space weather. Space weather affects international commerce. Thus, it is essential for SWORM to encourage U.S. subject matter expert participation in international standards-making bodies' technical committees (e.g., International Organization for Standards (ISO)) that develop standards related to the space environment.

CHAPTER 11: Next Steps

SWORM has made significant progress over the last nine years to build awareness and move the Nation towards resilience to space weather through coordinating operations, research, and mitigation activities across the Federal executive branch. However, technology, infrastructure systems, and national priorities continue to evolve–with the space domain becoming increasingly important to national and economic security.

The findings identified by SWAG provide a strong set of recommendations that, if implemented, will dramatically advance the national space weather enterprise. They will enable greater coordination, collaboration, and opportunities to prioritize space weather activities to achieve improved tools and capabilities, leading ultimately to national and global resilience to space weather.

SWAG looks forward to engaging SWORM agencies and other relevant stakeholders on these findings and recommendations. SWAG looks forward to advising SWORM on the implementation of these findings and recommendations and any subsequent update or reevaluation of the National Space Weather Strategy and Action Plan, or other relevant plans, policies, or strategies, pursuant to 51 USC 60601(d)(2)(D). SWAG will seek to provide additional input on resilience focused actions and other needs of end users in the forthcoming results of the user-needs surveys pursuant to 51 USC 60601(d)(3).

APPENDIX 1: Abbreviations, Acronyms, and Definitions

AI/ML	Artificial intelligence / machine learning
CRADA	Cooperative Research and Development Agreement
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
FAA	Federal Aviation Administration
FERC	Federal Energy Regulatory Commission
FTE	full-time equivalent (employee)
GDC	Geospace Dynamics Constellation
GEO	Geostationary orbit
GIC	Geomagnetically induced current
GONG	Global Oscillation Network Group
GTO	Geostationary transfer orbit
HSO	Heliophysics System Observatory
IMAP	Interstellar Mapping and Acceleration Probe
ISAC	Information Sharing and Analysis Center
ISO	International Organization for Standards
LEO	Low-Earth orbit
MEO	Medium Earth orbit
MOAs	Memoranda of agreement

MOUs	Memoranda of understanding
MT	Magnetotelluric
MTM	Mission Traceability Matrix
NASA	National Aeronautics and Space Administration
National space weather enterprise	The combination of the space weather enterprises across the Federal Government, the commercial sector, and the academic sector
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
NSF	National Science Foundation
NSTC	National Science and Technology Council
NWS	National Weather Service
O2R	Operations to research
OAR	(NOAA) Oceanic and Atmospheric Research
OMB	(White House) Office of Management and Budget
OSC	(NOAA) Office of Space Commerce
OSTP	(White House) Office of Science and Technology Policy
OTM	Operational Traceability Matrix
PPD	Presidential Policy Directive
PROSWIFT	Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act
R2O	Research to operations
R2O2R	Research-to-operations and operations-to -research
SBIR	Small Business Innovations Research
SEESAW	Space Environment Engineering and Science Applications Workshop

State	Department of State
STM	Science Traceability Matrix
SWAG	Space Weather Advisory Group
SWFO-L1	Space Weather Follow-On Lagrange-1
SWORM	Space Weather Operations, Research, and Mitigation (NSTC Subcommittee)
SWPC	(NOAA's) Space Weather Prediction Center
Testbed	A working relationship for developmental testing in a quasi--operational framework among researchers and operational scientists or experts (such as measurement specialists, forecasters, IT specialists) including partners in academia, the private sector, and government agencies, aimed at solving operational problems or enhancing operations, in the context of user needs. A successful testbed involves physical assets as well as substantial commitments and partnerships (NAO 216-105B)
THEMIS	Time History of Events and Macroscale Interactions during Substorms Mission
USC	United States Code
USGS	U.S. Geological Survey
VLEO	Very low earth orbit
VTEC	Vertical total electron content

APPENDIX 2: Space Weather Advisory Group Charter

U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SPACE WEATHER ADVISORY GROUP

CHARTER

1. Committee's Official Designation. The committee shall be known as the Space Weather Advisory Group (hereinafter the "SWAG").

2. Authority. The Administrator of the National Oceanic and Atmospheric Administration (NOAA) is required to establish the SWAG pursuant to the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act of 2020 (Public Law 116-181) and in consultation with other relevant Federal agencies. The SWAG shall function as an advisory body in accordance with the Federal Advisory Committee Act (FACA), as amended, 5 U.S.C. App.

3. Objectives and Scope of Activities. The SWAG shall advise the Space Weather Interagency Working Group (hereinafter the "interagency working group") established by the National Science and Technology Council pursuant to Section 60601(c) of title 51, United States Code. This advice will inform the interests and work of the interagency working group.

4. Description of Duties. The advisory group shall advise the interagency working group on the following:

a. Facilitating advances in the space weather enterprise of the United States;
b. Improving the ability of the United States to prepare for, mitigate, respond to, and recover from space weather phenomena;
c. Enabling the coordination and facilitation of research to operations and operations to research, as described in section 60604(d) of title 51, United States Code; and
d. Developing and implementing the integrated strategy under section 60602 of title 51, United States Code, including subsequent updates and reevaluations.

The SWAG shall also conduct a comprehensive survey of the needs of users of space weather products to identify the space weather research, observations, forecasting, prediction, and modeling advances required to improve space weather products, as required by section 60601(d)(3) of title 51, United States Code. Not later than 30 days after the completion of the survey, the advisory group shall provide to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a briefing on the results of the survey. Within 30 days of the briefing to Congress, the advisory group shall make the results of the survey publicly available. The advisory group shall review and assess the survey not less than every 3 years and update, resubmit, and republish the survey.

5. Agency or Official to Whom the Committee Reports. The SWAG shall report to the interagency working group, in coordination with the Designated Federal Officer (DFO).

6. Support. The National Oceanic and Atmospheric Administration (NOAA) shall make available to the SWAG such information, personnel, and administrative services as may be reasonably required to accomplish the duties of the SWAG, subject to the availability of appropriations. NOAA will also provide a DFO for the SWAG.

7. Estimated Annual Operating Costs and Staff Years.

a. The estimated annual operating costs, to include travel, meetings, and possible contracting support, is initially estimated to be $60,000 and 0.5 full-time equivalent (FTE) staff support per annum.
b. Members of the SWAG will not be compensated for their services, but may upon request be allowed travel and per diem expenses as authorized by 5 U.S.C. § 5701 et seq.

8. Designated Federal Officer. The Administrator of NOAA will designate a full-time or permanent part-time employee, appointed in accordance with Department of Commerce procedures, to serve as the Designated Federal Officer (DFO). The DFO will approve or call all of the SWAG meetings and subcommittee meetings; prepare and approve all meeting agendas; attend all the SWAG and subcommittee meetings; adjourn any meeting when the DFO determines adjournment to be in the public interest; and chair meetings when directed to do so by the Administrator of NOAA.

9. Estimated Number and Frequency of Meetings. The SWAG will meet approximately 3 times each year, which may be conducted in person or by teleconference, webinar, or other means. Additional meetings may be called as appropriate, with approval by the Administrator of NOAA. Members are expected to attend all meetings. If a member should miss more than 2 consecutive meetings without the permission of the Chair, that individual's membership will be reviewed by the interagency working group.

10. Duration. Continuing.

11. Termination. Pursuant to section 60601(d)(4) of title 51, United States Code, section 14 of the FACA, as amended, 5 U.S.C. App., shall not apply to the advisory group. The charter shall terminate 4 years from the date of its filing with the appropriate U.S. Senate and House of Representatives Committees unless earlier terminated or renewed by proper authority.

12. Membership and Designation.

a. The advisory group shall be composed of not more than 15 members appointed by the interagency working group, of whom—

i. 5 members shall be representatives of the academic community;

ii. 5 members shall be representatives of the commercial space weather sector; and

iii. 5 members shall be nongovernmental representatives of the space weather end user community.

Members should be chosen to provide an appropriate range of views that represent the span of the space weather community and end-user sectors.

b. Not later than 30 days after the date on which the last member of the advisory group is appointed under subparagraph (a), the Administrator of NOAA shall appoint 1 member as the Chair of the SWAG.

c. The length of the term of each member of the advisory group shall be 3 years beginning on the date on which the member is appointed.

i. Term Limits.

1. In general. A member of the advisory group may not serve on the advisory group for more than 2 consecutive terms.

2. Chair. A member of the advisory group may not serve as the Chair of the advisory group for more than 2 terms, regardless of whether the terms are consecutive.

d. Members shall serve in a representative capacity, expressing the views and interests of the respective space weather community and/or end-user sector; they are, therefore, not Special Government Employees. As such, members are not subject to the ethics rules applicable to Government employees, except that they must not misuse Government resources or their affiliation with the Committee for personal purposes.

e. Members will be selected on a clear, standardized basis, in accordance with applicable Department of Commerce guidance.

f. Members shall not reference or otherwise utilize their membership on the SWAG in connection with public statements made in their personal capacities without a disclaimer that the views expressed are their own and do not represent the views of the SWAG, NOAA, the Department of Commerce, or the interagency working group.

13. Subcommittees. NOAA may establish such subcommittees, task forces, and working groups consisting of SWAG members – as may be necessary subject to the provisions of FACA, the FACA implementing regulations, and applicable Department of Commerce guidance. Subcommittees and other subgroups of the SWAG must report back to the parent committee (SWAG) and must not provide advice or work products directly to NOAA, the Department of Commerce, or the interagency working group.

14. Record-keeping. The records of the SWAG, formally and informally established subcommittees, or other subgroups of the committee, shall be handled in accordance with General Records Schedule 6.2 or other approved agency records disposition schedule. These records shall be available for public inspection and copying, subject to the Freedom of Information Act, 5 U.S.C. § 552.

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Filing Date

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STEPHEN KUNZE

Digitally signed by

STEPHEN KUNZE

Date: 2021.04.21

APPENDIX 3: Space Weather Advisory Group Membership

End-Users:

- Tamara Dickinson, President, Science Matters Consulting, Washington, DC (Chair)
- Rebecca Bishop, Principal Scientist, The Aerospace Corporation., El Segundo, CA
- Craig Fugate, Chief Emergency Management Officer, One Concern, Gainesville, FL
- Mark Olson, Senior Engineer and Manager, Reliability Assessments, North American Electric Reliability Corporation, Atlanta, GA
- Michael Stills, Retired, (former) Director, Flight Dispatch, Network Operation Control Center, United Airlines, Ashburn, VA

Commercial Providers:

- Nicole Duncan, Heliophysics Mission Area Lead, Ball Aerospace, Boulder, CO
- Jennifer Gannon, VP of Research and Development, Computational Physics, Inc. Lafayette, CO
- Seth Jonas, Principal, Lockheed Martin, Bethesda, MD
- Conrad Lautenbacher, Executive Chairman, GeoOptics, Inc., Dunwoody, GA
- Kent Tobiska, President, Space Environment Technologies, Pacific Palisades, CA

Academia:

- Heather Elliott, Staff Scientist, Southwest Research Institute, San Antonio, TX
- Tamas Gombosi, Distinguished Professor, University of Michigan, Ann Arbor, MI
- George Ho, Chief Scientist (Instrumentation), Johns Hopkins University Applied Physics Laboratory, Laurel, MD
- Delores Knipp, Research Professor, University of Colorado, Boulder, CO
- Scott McIntosh, Deputy Director, National Centers for Atmospheric Research, Boulder, CO

APPENDIX 4: January 2023 SWAG Meeting Agenda

Fourth Meeting of the Space Weather Advisory Group
18–19 Jan 2023
9:00 AM–5:00 PM ET
20 Jan 2023
9:00 AM–12:00 PM ET
Agenda
(All times in ET)

Wednesday, 18 Jan 2023

9:00 – 9:05 AM	**Welcome** Jennifer Meehan, NOAA NWS, DFO SWAG, and Executive Secretary, SWORM
9:05 – 9:15 AM	**Opening Remarks and Recap of Meeting 3** Tamara Dickinson, Science Matters Consulting and Chair, SWAG • March and June 2022 SWAG Meeting Minutes **DECISIONAL**
9:15 – 9:30 AM	**Progress Since Meeting 3** Tamara Dickinson, Science Matters Consulting and Chair, SWAG **INFORMATIONAL**
9:30 – 9:45 AM	**NOAA Administrator Remarks** Rick Spinrad, Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator **INFORMATIONAL**
9:45 – 10:15 AM	**SWORM Subcommittee Co-Chair Remarks** • Ezinne Uzo-Okoro, Assistant Director for Space Policy, Office of Science and Technology Policy • Mary Erickson, Deputy Assistant Administrator for Weather Services, Deputy Director, National Weather Service • Mona Harrington, Assistant Director, National Risk Management Center, Cybersecurity and Infrastructure Security Agency, Department of Homeland Security **INFORMATIONAL**
10:15 – 10:30 PM	**Committee Discussion**

10:30 – 11:00 AM	**Break**
11:00 – 11:30 AM	**Related Activities** ● National Academy of Sciences Space Weather Roundtable Sarah Gibson (UCAR) and Geoff Crowley (Orion Space), Co-Chairs ● NASA Space Weather Council Nicole Duncan (Ball Aerospace), Chair **INFORMATIONAL**
11:30 AM – 12:00 PM	**Current Status of Implementing the National Space Weather Strategy and Action Plan** Bill Murtagh, Program Coordinator, NWS Space Weather Prediction Center **INFORMATIONAL**
12:00 – 1:00 PM	**Lunch**
1:00 – 2:00 PM	**1.1 Observational Data and Access (Ground-based)** Co-Chairs: Jenn Gannon (CPI) and George Ho (JHU APL) ● Anthea Coster (MIT) ● Roger Varney (UCLA) ● Alan Liu (NSF) ● Asti Bhatt (SRI International) **INFORMATIONAL**
2:00 – 3:00 PM	**1.2 Economic Assessment** Co-Chairs: Seth Jonas (Lockheed) and Delores Knipp (UC Boulder) ● Jonathan Eastwood (Imperial College) ● Tina Highfill (Bureau of Economic Analysis, DOC) ● Terry Griffin (KSU) **INFORMATIONAL**
3:00 – 3:30 PM	**Break**
3:30 – 4:55 PM	**Committee Discussion - Day 1 Recommendations** **INFORMATIONAL**
4:55 – 5:00 PM	**Closing Remarks** Tamara Dickinson, Science Matters Consulting and Chair, SWAG

5:00 PM	**Adjourn Day 1**

Thursday, 19 Jan 2023

9:00 – 9:05 AM	**Welcome** Jennifer Meehan, NOAA NWS, DFO SWAG, and Executive Secretary, SWORM
9:05 – 9:15 AM	**Opening Recap of Day 1** Tamara Dickinson, Science Matters Consulting and Chair, SWAG
9:15 – 10:40 AM	**2.1 Observational Data, Access, and Infrastructure in Space** Co-Chairs: Nicole Duncan (Ball Aerospace) and Heather Elliott (SWRI) ● Neal Nickles (Ball Aerospace) ● Sean Elvidge (University of Birmingham) ● Sarah Gibson (UCAR) ● Lisa Upton (SWRI) ● Slava Merkin (APL) **INFORMATIONAL**
10:40 - 11:00 AM	**Break**
11:00 – 11:45 AM	**2.2 Benchmarks, Metrics, and Scales** Co-Chairs: Kent Tobiska (SET), Craig Fugate (former FEMA), and Mike Stills (retired UA) ● Steve Morley (Los Alamos National Laboratory) ● David Boteler (Natural Resources Canada) ● Richard Horne (British Antarctic Survey) **INFORMATIONAL**
11:45 AM – 12:45 PM	**LUNCH**
12:45 – 1:45 PM	**2.3 Data Infrastructure and Methods** Co-Chairs: Jenn Gannon (CPI) and Tamas Gombosi (UMich) ● Sage Andorka (Space Force) ● Enrico Camporeale (University of Colorado) ● Rebecca Ringuette (NASA GSFC) ● Jacob Bortnik (UCLA) **INFORMATIONAL**

1:45 – 3:00 PM	**2.4 Evolving Infrastructure Systems and Services** Co-Chairs: Seth Jonas (Lockheed) and Mark Olson (NERC) ● Emanuel Bernabeu (PJM) ● Steve Stone (Lockheed) ● Yari Collado-Vega (NASA GSFC) ● Rich DalBello (NOAA, Office of Space Commerce) **INFORMATIONAL**
3:00 – 3:30 PM	**BREAK**
3:30 – 4:30 PM	**2.5 Industry and Government Collaborations, Coordination, Outreach, and Communications on Space Weather** Co-Chairs: Rebecca Bishop (Aerospace Corp) and Scott McIntosh (UCAR) ● Dipak Srinivasan (APL) ● Yuri Shprits (UCLA) ● Bob Arritt (EPRI) ● Erin Miller (Information Sharing and Analysis Center) **INFORMATIONAL**
4:30 – 5:00 PM	**Public Comments**
5:00 – 5:30 PM	**Committee Discussion - Overnight Assignments** **DECISIONAL**
5:30 – 5:35 PM	**Closing Remarks** Tamara Dickinson, Science Matters Consulting and Chair, SWAG
5:35 PM	**Adjourn Day 2**

Friday, 20 Jan 2023

9:00 – 9:05 AM	**Welcome** Jennifer Meehan, NOAA NWS, DFO SWAG, and Executive Secretary, SWORM
9:05 – 9:15 AM	**Opening Recap of Day 2** Tamara Dickinson, Science Matters Consulting and Chair, SWAG
9:15 – 10:30 AM	**Committee Discussion - National Space Weather Strategy and Action Plan Update** **DECISIONAL**
10:30 – 11:00 AM	**Break**
11:00 – 11:50 AM	**Committee Discussion - Writing Assignments** **DECISIONAL**
11:50 – 12:00 PM	**Closing Remarks** Tamara Dickinson, Science Matters Consulting and Chair, SWAG Jennifer Meehan, NOAA NWS, DFO SWAG, and Executive Secretary, SWORM
12:00 PM	**Adjourn Day 3**

Public Access and Webinar Instructions:

To attend the SWAG meeting via webinar, please see registration links below. You must register in advance of the meeting. After registering for the webinar, you will receive a confirmation email containing information about joining the webinar. Please note that all webinar attendees, with the exception of the SWAG members and SWORM representatives, will be muted and only able to listen/view the meeting activities.

Link for registration: https://register.gotowebinar.com/register/5477934483266986077