2023 Space Weather Enterprise Forum

Summary Report

Submitted by: National Environmental Satellite, Data, and Information Service
National Oceanic and Atmospheric Administration

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Executive Summary

The Space Weather Enterprise Forum (SWEF) is an annual meeting of space weather stakeholders, policymakers, senior government leaders, researchers, service provider agencies, private-sector service providers, space weather information users, and legislators and staff from Capitol Hill. The meeting's goal is to address the state of Nation's space weather monitoring and prediction capabilities and discuss priorities for the years ahead. The purpose of SWEF is to raise awareness of space weather and its effects on critical infrastructure and its societal relevance in the current technology-dependent world. It provides a platform to engage in constructive, forward-looking dialogues and identify solutions for improving space weather prediction capabilities and enhancing the Nation's resilience to space weather through public-private cooperation.

This year, the Office of Space Weather Observations (SWO), formerly the Office of Projects, Planning, and Analysis (OPPA), in National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) organized SWEF on behalf of the Interagency Council for Advancing Meteorological Services (ICAMS). The theme of the 2023 SWEF was "Harnessing Partnerships to Meet the Challenges of Extreme Space Weather". The meeting agenda for this year's SWEF included topics related to progress by the space weather community in response to the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act, recommendations of the Space Weather Advisory Group (SWAG), and the Nation's preparedness for the upcoming solar maximum phase.

Dr. Elsayed Talaat, Director of SWO, opened the forum by welcoming participants to the 2023 SWEF and introducing keynote speakers. This year, SWEF was fortunate to have four distinguished speakers: the Honorable Gary Peters, Senator from Michigan, Chairman of the Senate Homeland Security and Governmental Affairs Committee and Sponsor of the PROSWIFT Act; the Honorable Dr. Rick Spinrad, Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator; the Honorable Frank Lucas, US Congressman from Oklahoma and Chairman of the House Science, Space and Technology Committee; and Dr. Ezinne Uzo-Okoro, Assistant Director for Space Policy for the White House Office of Science and Technology Policy.

The keynote remarks were followed by technical sessions. Session 1, on the PROSWIFT Progress, highlighted efforts of the space weather community on implementing PROSWIFT directives. Speakers in this session included leadership from several government agencies and the private sector who shared their views on the progress and challenges in implementing PROSWIFT directives. Session 2 brought together several members of the SWAG in an interactive panel-based format to discuss the group's findings and recommendations, released in their April 2023 report, to successfully implement the PROSWIFT Act and transform the space weather enterprise.

The afternoon program was kicked off by special remarks from The Honorable Dr. Michael Morgan, Assistant Secretary of Commerce for Environmental Observation and Prediction, followed by spotlight talks from the leadership of the National Center for Atmospheric Research

and Lockheed Martin. Session 3 presented perspectives from NOAA's Space Weather Prediction Center (SWPC) and the Federal Emergency Management Agency (FEMA) on efforts being pursued to prepare and plan for space weather events. Following the same theme as Session 3, Session 4 presented the industry perspective on space weather planning and preparedness with presentations form American Airlines, Dominion Energy Inc., and the University of Minnesota. The technical program of the 2023 SWEF concluded with Session 5, moderated by Mr. Craig Fugate, former FEMA administrator. It included a panel discussion on future work and associated challenges in establishing a space weather-resilient Nation, as we approach the maximum phase of the current solar cycle.

Table of Contents

1. Space Weather Enterprise Forum

SWEF is an annual meeting of space weather stakeholders, senior government leaders, policymakers, and legislators and staff from Capitol Hill to address the state of Nation's space weather prediction capabilities and discuss priorities for the year ahead. The purpose of SWEF is to raise awareness of space weather and its effects on critical infrastructure and its societal relevance in the current technology-dependent world. The forum provides an opportunity for experts, scientists, industry leaders, and policymakers to convene, exchange information, and discuss the latest developments in space weather research, forecasting, and mitigation efforts. By effectively communicating community activities through this forum, policymakers can gain a comprehensive understanding of the current state of space weather science, technology, and preparedness. This knowledge empowers them to make informed decisions, allocate resources, and develop policies that promote the resilience of critical infrastructure and safeguard society from the adverse effects of space weather events. Ultimately, SWEF plays a vital role in bridging the gap between the space weather community and policymakers, ensuring that crucial information is shared, and proactive measures are taken to protect our technological systems and society at large.

The first SWEF was conducted in 2007 and, until 2019, it was organized through the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM). There was a brief hiatus in SWEF due to the COVID-19 pandemic. In 2022, the organization of the meeting was passed on to the Interagency Council for Advancing Meteorological Services (ICAMS) due to the dissolution of OFCM. In 2023, OPPA (now SWO) in NOAA/NESDIS organized SWEF on behalf of ICAMS. This year's forum took place on Capitol Hill in the Russell Senate Office Building. It was a one-day event with several sessions focusing on different applications areas of space weather. The theme of this year's SWEF was "Harnessing Partnerships to Meet the Challenges of Extreme Space Weather." The agenda covered a wide range of topics, such as implementation of the PROSWIFT Act, industry and government planning and preparedness for space weather, and the Nation's preparedness to the upcoming solar maximum phase. The forum featured keynote remarks from Senator Gary Peters, NOAA Administrator Dr. Rick Spinrad, Representative Frank Lucas, and OSTP Assistant Director for Space Policy Dr. Ezinne Uzo-Okoro. Dr. Michael Morgan, NOAA's Assistant Secretary of Commerce for Environmental Observation and Prediction, kicked off the afternoon program with special remarks.

2. 2023 SWEF Planning

The Chair of the organizing committee led the planning for the 2023 SWEF. The 2023 SWEF Organizing Committee members are listed below:

Irfan Azeem (Chair)	National Oceanic and Atmospheric Administration
Erin Lynch	National Oceanic and Atmospheric Administration

Krystal Azelton	Secure World Foundation
Michael Bonadonna	Office of System Architecture and Advanced Planning, NOAA
Tamara Dickinson	Science Matters Consulting
Devrie Intriligator	Carmel Research Center
Jennifer Meehan	National Oceanic and Atmospheric Administration
Lt. Col. Omar Nava	US Air Force
Bill Murtagh	National Oceanic and Atmospheric Administration
Mangala Sharma	National Science Foundation
James Spann	National Aeronautics and Space Administration
Genene Sossa	National Aeronautics and Space Administration
Josh Wolny	Department of State
Genene Fisher	National Aeronautics and Space Administration
Jenn Gannon	Computational Physics, Inc.
Ron Keen	Department of Homeland Security

3. 2023 SWEF Sponsors

The 2023 Space Weather Enterprise Forum was sponsored by the Southwest Research Institute (SwRI) and the Secure World Foundation.

4. 2023 SWEF Session Summaries

Opening Remarks

Welcome from the Organizer - Dr. Elsayed Talaat, Director, Office of Projects, Partnerships, and Analysis, NOAA

Dr. Talaat began his opening remarks by expressing how exciting it is to hold the SWEF in person again after a two-year hiatus. Much happened during those years leaving many topics to discuss at this year's forum. He described the unique opportunity that SWEF offers to engage directly with policy makers, senior government leaders, researchers, government service provider agencies, commercial service providers, space weather information users, media, and legislators and staff from Capitol Hill. He characterized space weather as a global challenge that will require the sustained partnership of all stakeholders to ensure that we have a space weather ready nation. Dr. Talaat then introduced the first keynote speaker. Senator Gary Peters of Michigan was a primary sponsor of the PROSWIFT Act, which directs the federal agencies that study and predict space weather to coordinate with the private sector to assess the potential impacts of space weather on the United States and determine what new research and technologies are needed to improve the ability to forecast space weather events and mitigate

potential damage. Senator Peters could not attend in person; however, as a great champion of space weather, he kindly sent recorded remarks.

Keynote Remarks: The Honorable Gary Peters (recorded), US Senator from Michigan, Chairman of the Senate Homeland Security and Governmental Affairs Committee and Sponsor of the PROSWIFT Act

Senator Peters began by describing how vital the work is to mitigate the effects of extreme space weather to our national security and economy. Research shows that extreme space weather events have the potential to catastrophically disrupt our infrastructure, including electric power grids, communications networks, aircraft, and satellites. Improving our understanding of extreme space weather events is critical to make sure we are equipped and prepared to handle them in real time. He thanked all participants in the 2023 SWEF. He recounted the signing of the PROSWIFT Act into law in 2020, which strengthened the nation's ability to predict severe space weather events, thereby mitigating harmful impacts here on Earth. He was proud to offer this bipartisan legislation into law to reinforce the United States' global leadership in the field. He looks forward to working with the PROSWIFT partners to implement further measures to protect the nation from these events. He closed by reiterating his thanks to the space weather community.

Keynote Remarks: The Honorable Richard Spinrad, Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator

Dr. Talaat introduced the Undersecretary of Commerce for Oceans and Atmosphere and the NOAA Administrator, Dr. Richard Spinrad. Dr. Spinrad is responsible for the strategic direction and oversight of the agency and its over twelve thousand employees. This includes developing NOAA's portfolio of products and services to address the climate crisis, enhance environmental sustainability, foster economic development, and create a more just, equitable, diverse, and inclusive NOAA workforce.

Dr. Spinrad opened his remarks by expressing gratitude for the invitation and acknowledging the other keynote speakers and their roles in advancing the space weather enterprise. He thanked Chairman Lucas for his support of the PROSWIFT Act and the key provisions that improve our ability to forecast and mitigate the effects of space weather. In particular, he thanked Chairman Lucas for highlighting the need to engage with the private sector and championing the commercial data buy provision. He described this year's theme of harnessing partnerships to meet the challenges of extreme space weather as particularly appropriate. He thanked Senator Peters for his role in ensuring that there is legislation in place, empowering the agencies to take the necessary actions to prepare and protect the nation against space weather phenomena. Since the PROSWIFT Act was signed in 2020, all agencies have been very busy because of the potential for space weather storms to paralyze critical infrastructure, resulting in the nation's first trillion-dollar disaster. He described the urgency to get the nation ready for and responsive to space weather as we approach solar maximum, and the need to do this in partnership.

Dr. Spinrad highlighted the vulnerability of the power grid to space weather and cited a 2020 study that found space weather observations, products, and services can generate economic benefits to the power industry by reducing or eliminating operational and service interruption

costs during a space weather event. NOAA's space weather observations, products, and services can generate approximately $31 billion of economic benefits to the electric power industry during a 16-hour outage in a highly populated area. Dr. Spinrad described the importance of the strategic partnership between NOAA and NASA in monitoring Earth's complex systems, near-Earth space, the Sun, and solar wind. While NOAA is the Nation's authoritative source for operational weather, climate, ocean, cryosphere, environmental, and space weather products and services, NASA is the Nation's lead agency for fundamental and applied Earth system science and space weather research. He detailed the team of line offices across NOAA that are working together to provide actionable space weather information in a whole-of-NOAA effort.

Dr. Spinrad emphasized the establishment of NOAA's Office of Space Weather Observations (from OPPA), which develops, deploys, and sustains flight projects and ground-based infrastructure for collecting and disseminating operational space-based space weather measurements. He also highlighted NOAA's Space Weather Prediction Center (SWPC), the Nation's official source of civil space weather information, including forecasts, alerts, and warnings to the public and customers used to protect crucial infrastructure such as satellites and the power grid. He went on to highlight NOAA's Office of Space Commerce, which will provide basic space situational awareness and space traffic coordination services. He mentioned that within the Department of Commerce, sister bureaus can also help with space weather information, including intellectual property protection with the Patent and Trademark office, overseas commerce with the International Trade Administration, and stimulating new business through the Economic Development Administration.

Dr. Spinrad described the actions that NOAA has taken in response to the PROSWIFT Act, including sustaining and enhancing critical observations, identifying research needs and promoting opportunities for research-to-operations and operations-to-research collaborations, advancing space weather models, and understanding the needs of space weather end users. He detailed specific steps NOAA has taken to further each of these goals. To sustain and enhance critical observations, NESDIS reorganized to create the SWO office, which is dedicated to developing and deploying space weather satellite systems that will deliver observations to SWPC, the US Air Force 557th Weather Wing, and NASA. NOAA is a signatory in a Memorandum of Agreement with NASA, National Science Foundation (NSF), and the Department of the Air Force that will foster the transition of capabilities into operations. Additionally, NOAA established a testbed in SWPC that is connected directly to ongoing model research that NASA and NSF conduct. NOAA works in partnership with federal and international agencies and the academic community to develop a Sun-to-Earth Modeling Continuum for space weather, with the goal of advancing space weather models. Recently, NOAA worked with the US Geological Survey to implement the US Geoelectric Field Model into operations, which now includes Canada through work with the National Resources Canada/Canadian Hazards Information Service.

Dr. Spinrad also emphasized NOAA's commitment to the Commercial Data Program to demonstrate the quality and impact of commercial data on NOAA's space weather forecast models. He also referenced the work of SWAG, a non-governmental advisory group managed by NOAA, authorized by the PROSWIFT Act to conduct a survey of user needs for space weather products. Dr. Spinrad closed his remarks by stressing the importance of the work being done by

the space weather community to address the Nation's needs for space weather services in a time of increasing solar activity, as we ramp up to the next solar maximum expected in 2025. He further emphasized the distinct role of each of the partners in the space weather enterprise and the need to continue to foster strong partnerships across federal agencies and between the public and private sectors, to enable the United States to address space weather phenomena.

Keynote Remarks: The Honorable Frank Lucas, US Congressman from Oklahoma and Chairman of the House Science, Space and Technology Committee

Dr. Talaat introduced the next keynote speaker, Congressman Frank Lucas from Oklahoma and Chairman of the House Science, Space, and Technology Committee. On the Committee, Congressman Lucas ensures that we, as a nation, harness American innovation to improve energy efficiency and effectiveness, support research and basic science labs, improve access to STEM education while building the American STEM workforce, and maintain American global leadership in space exploration.

Chairman Lucas opened his remarks by recounting his time in the Oklahoma State House before coming to Congress. He recalled his work on the committee to expand our ability to better predict and respond to space weather. He described how the expansion of the presence in low earth orbit and the potential impact of space weather will only continue to grow. Interference with GNSS systems and communications can have ripple effects throughout the economy. For example, in agriculture where these technologies are being adopted more and more. He announced a space weather exercise that the Department of Agriculture will conduct later this year to explore those impacts. He highlighted the need for collaboration between the government, academia, and the commercial sector, if we are going to be successful at forecasting and responding to space weather incidents.

Congressman Lucas emphasized how important it was to him that the PROSWIFT Act include an amendment directing NOAA to establish a pilot program to collect data from commercial space weather companies. The tremendous growth in the commercial space weather industry in his view makes the industry an ideal partner to improve space weather observations and forecasting. He recounted the history of NOAA, which was formed by an executive order rather authorized by law. Such a law that establishes an agency and lays out its mission and purpose is called an Organic Act. Chairman Lucas described his view that the lack of such legislation for NOAA is problematic given its size, scope, and importance, as well as its location within another government department. He has introduced a NOAA Organic Act that would enshrine its position in law and stand it up as an independent agency, like NASA. He further described his reasons for introducing this bill, including facilitating the appropriations process for authorized activities. Chairman Lucas described this bill as one of his highest priorities in Congress to improve our ability to predict, prepare for, and respond to space weather incidents. He closed by thanking the audience for the important work improving our understanding and ability to mitigate space weather impacts.

Keynote Remarks: Dr. Ezinne Uzo-Okoro, Assistant Director for Space Policy, White House Office of Science and Technology Policy

Dr. Talaat introduced the final keynote speaker of the morning session. Dr. Ezinne Uzo-Okoro is the Assistant Director for Space Policy for the White House Office of Science and Technology Policy. Dr. Uzo-Okoro leads the aeronautics, space, and manufacturing portfolios, and has released policy on Aeronautics Priorities, Earth Observations, Orbital Debris, Microgravity research, Space Weather, In-space Servicing Assembly and Manufacturing, and Advanced Manufacturing. Dr. Uzo-Okoro is also the OSTP Co-Chair of SWORM.

Dr. Uzo-Okoro opened her remarks by thanking Congressman Lucas and Senator Peters for their efforts to pass the PROSWIFT Act and continued support for building a space weather resilient nation. She thanked Dr. Spinrad for the contributions of NOAA's National Weather Service and NESDIS. In managing the space weather portfolio at OSTP, Dr. Uzo-Okoro described her responsibility to ensure that the over thirty federal departments and agencies meet the goals and objectives specified in the 2019 National Space Weather Strategy and Action Plan. She highlighted the particular importance of NOAA's role in this effort. The Space Weather Operations, Research, and Mitigation Committee (SWORM), lead out of OSTP, which includes coordination amongst federal agencies to ensure the actions outlined in the PROSWIFT Act are carried out, and this work is overseen by OSTP. She recounted 2014, when the director at the time, Dr. John Holdren, ordered the establishment of a space weather interagency subcommittee, which brought together all elements of scientific and homeland security enterprises of the federal government to address space weather for the first time.

SWORM released the first Space Weather Strategy and Action Plan in 2015 with an update in 2019. The 2019 Strategy outlined the collaborative and federally-coordinated approach to developing effective policies, practices, and procedures for decreasing the nation's vulnerabilities to space weather. In the PROSWIFT Act, Congress codified OSTP and the existing federal government interagency group responsibility to coordinate space weather efforts within the government. She emphasized that the government cannot achieve these goals alone. Incorporating the technological and scientific knowledge in academia and the private sector is essential to support resilience against space weather. She described the key role of SWAG, which includes commercial service providers, academia, and end users who advise the SWORM.

Dr. Uzo-Okoro also highlighted the role of the Space Weather Roundtable established by the National Academies in facilitating communication and knowledge transfer among the space weather enterprise. The Roundtable engages stakeholders across several disciplines with a focus on issues and challenges that require in depth exploration. She emphasized that the extraordinary growth of satellites in low earth orbit, the goals for human space exploration and return to the moon, and our ever-growing reliance on technologies that are vulnerable to space weather demand that we work to better understand and predict space weather and mitigate its effects. The framework provided by the PROSWIFT Act and our National Space Weather Strategy and Action Plan will serve to prioritize our space weather activities. She closed by remarking on the challenges posed by an extreme space weather event to the nation's preparedness and resilience and reiterating the commitment improving national preparedness for all space weather events.

Session 1: PROSWIFT Progress

Session Chair: Mr. William Murtagh, Program Coordinator, Space Weather Prediction Center, NOAA.

Mr. Murtagh introduced the session by providing brief remarks about the PROSWIFT Act. He also noted that the PROSWIFT Act calls for the United States to prepare and protect against the social and economic impacts of space weather and promotes a whole community approach to build a space weather resilient nation. The session provided an opportunity for the leadership of several federal agencies and the commercial sector to share their thoughts on the progress and the challenges in implementing PROSWIFT activities within their respective organizations. By way of introduction, Bill Murtagh gave a brief biographical sketch of the session speakers.

Dr. David Applegate, Director, U.S. Geological Survey

Dr. Applegate's presentations focused on the role of the US Geological Survey (USGS) in the space weather enterprise. He noted that the USGS plays a vital role in the space weather enterprise, focusing on characterizing the ground impacts of magnetic storms caused by space weather events, with partnerships being crucial for their success. As part of the Department of the Interior, the USGS is committed to delivering science for environmental, resource, and public safety concerns. USGS's mission revolves around providing actionable information to decision-makers, including critical infrastructure and underserved communities. The agency's involvement in space weather falls under its natural hazards mission that provides ground-based magnetic field monitoring, which feeds directly into NOAA/SWPC to help enable their critical warnings.

The USGS's role in the space weather enterprise is carried out through their geomagnetism program, which observes and researches variations in Earth's magnetic field and the intensity of magnetic storms. Their responsibilities are linked to executive orders and legislation, such as the PROWIFT Act. The USGS operates 14 geomagnetic observatories across the United States, transmitting real-time data to their Geologic Hazards Science Center and other agencies involved in space weather. These observatories support various applications, including navigation, geological studies, and deep earth dynamics research.

Dr. Applegate indicated that efforts are underway to expand the observatory footprint and complete the magneto-telluric survey. He highlighted USGS's active participation in the Space Weather Strategy and Action Plan, including revising benchmarks, conducting surveys, and expanding the geomagnetic observatory network. He also noted that the data collected from USGS's magnetic observatories are made openly accessible to various stakeholders, including NOAA, the Air Force, NASA, international space weather agencies, and the private sector. These data support navigation, geological studies, mineral assessments, directional drilling, and deep earth dynamics research. USGS's efforts in space weather also involve completing the magneto-telluric survey for the continental US to support geo-electric hazard calculations. By expanding ground-based monitoring, they aim to reduce uncertainties and better characterize space weather impacts, particularly geomagnetically induced currents that can affect the nation's power grid. USGS engages in targeted research, leveraging the operational data they collect, and collaborating on topics of national and societal importance related to space weather and geology. Dr. Applegate concluded by stating that the USGS is grateful to be part of the space weather

enterprise and is committed to providing valuable information to address one of the most significant hazards facing the nation and the world.

Ms. Irene Parker, Deputy Assistant Administrator for Systems, NESDIS, NOAA

Ms. Irene Parker presented an overview of activities NOAA is pursuing to implement PROSWIFT provisions. She began her remarks by highlighting her unique perspective as a non-scientist working at NOAA, emphasizing the importance of space weather. She stressed how space weather, including phenomena like solar flares and coronal mass ejections, significantly impacts daily life, from GPS systems and communication devices to electric vehicles and agriculture. She discussed NOAA's role in providing space weather forecasts, observations, and data management. She indicated that NOAA is recognized as a federal source of environmental intelligence, with expertise in understanding Earth's changing environment and operational space weather advisory services.

Ms. Parker also highlighted the need for reliable and continuous space weather observations, including partnerships with commercial entities, academia, and international collaborators. The importance of research, modeling, and collaboration between research and forecasting centers was emphasized. She acknowledged the need for increased federal engagement, both domestically and internationally, to develop the necessary infrastructure, data, and research to fulfill space weather mandates. Ms. Parker also discussed SWAG, which aims to gather perspectives from academia, users, and commercial providers to inform interagency efforts and address the diverse needs of space weather end-users. Additionally, the National Academies Space Weather Roundtable, involving experts and stakeholders from NSF, NASA, and NOAA, was highlighted as a platform for knowledge exchange and coordination. Concluding her presentation, Ms. Parker reiterated NOAA's commitment to understanding user needs, providing critical observations, and delivering timely and accurate space weather information and services. She restated NOAA's role as a trusted source of actionable space weather intelligence and emphasized the collective effort required to ensure the nation's leadership in space weather monitoring.

Ms. Peg Luce, Acting Director, Heliophysics Division, NASA

In her presentation, Ms. Luce discussed NASA's role in understanding fundamental physics, specifically in the context of heliophysics and space weather. NASA's contribution to the field involves conducting basic research, making space observations, developing new technologies and missions, and monitoring space weather for NASA's own missions. These efforts aim to provide the foundational understanding necessary for protecting ourselves from the effects of space weather. She provided a summary of NASA’s fleet of spacecraft, including the Parker Solar Probe and Voyager spacecraft, which study the Sun, the heliospheric environment, and the interaction with Earth. She noted that NASA has several missions in development and their comprehensive observing capability will help scientists shed light on aspects of space that are not yet fully understood, allowing for improved models and predictions.

Ms. Luce described how, over the years, NASA's heliophysics program has evolved, transitioning from directing research toward space weather to establishing a dedicated space

weather research program. This program leverages research to collaborate with other agencies and develop targeted research programs aimed at enhancing operations. Additionally, NASA is working on a new Grand Challenge opportunity to determine which dataset, if available in near real-time, would make the most significant difference. Ms. Luce provided a summary of NASA's involvement in initiatives like the SWORM and SWAG. NASA has taken steps in response to the PROSWIFT Act, such as ensuring operational assets like ACE, Wind, and Stereo continue to provide essential measurements. Furthermore, NASA supports the launch and access to space for missions such as Interstellar Mapping and Acceleration Probe (IMAP), which contribute to space weather observations. They are also investing in an international ground station capability for near real-time observations. She mentioned the quad agency Memorandum of Understanding (MOU) and the establishment of Space Weather Centers of Excellence. These centers aim to address complex space weather problems through multidisciplinary and multi-year efforts.

Ms. Luce stated that NASA's Moon to Mars program, which focuses on human exploration, also plays a role in advancing space weather understanding. The program aims to address high priority heliophysics science and space weather questions through a combination of human explorers and robotic systems in various locations, including the Moon, Mars, and deep space. She also highlighted upcoming solar eclipses in the United States, which present excellent opportunities for outreach and engagement with the public. She concluded her presentation by reiterating NASA's role in heliophysics and space weather, encompassing research, observation, technology development, and collaboration, with a focus on understanding and predicting space weather to protect human exploration.

Dr. Alexandra Isern, Assistant Director, Directorate for Geosciences, NSF

Dr. Isern expressed gratitude for the invitation to discuss the NSF contributions towards advancing space weather research. She outlined several broad categories of NSF priorities, including advancing basic and use-inspired research on space weather and solar physics, maintaining and improving ground-based observations of the sun and near-space, ensuring data availability to the public, bridging the gap between research and operations, and investing in the next generation workforce. She discussed NSF activities in three broad categories: research, infrastructure, and workforce development. Under the research category, Dr. Isern highlighted the ANSWERS program, which focuses on the Earth-Sun system as a whole and has invested approximately $12 million in seven projects across various institutions. These projects cover topics such as solar particle forecasting and the impacts of terrestrial processes on space weather.

In terms of research infrastructure, the NSF supports critical facilities like radar, LiDAR, and data centers, which not only provide data to researchers and operational users but also make it accessible to the public and educators. The importance of data centers associated with these facilities was emphasized for accessibility by researchers, operational users, educators, and students. Dr. Isern also highlighted the role NSF plays in facilitating the transition from research to operations through the development of models and investments in infrastructure. She stated that NSF has signed an MOU with other agencies to strengthen collaborative relationships for space weather Research-to-Operations-to-Research. Regarding workforce development, the NSF invests in programs that promote diversity and broaden participation in space weather research, including faculty development in Geospace Science to attract and support new faculty in tenure-

track positions. Throughout her presentation, Dr. Isern emphasized the importance of collaboration with the research community. She mentioned community feedback to the NSF via the Decadal Survey, the Space Weather Roundtable, and SWAG.

Dr. Joel Mozer, Director of Science, Technology and Research, U.S. Space Force

Dr. Mozer opened his remarks stating that the United States Department of Defense (DoD) and its newest military service, the United States Space Force (USSF), have a long-standing involvement in space weather research and operations. He spoke about factors driving DoD's interest in space weather. Firstly, as operators of numerous satellites in orbit, the DoD needs to comprehend the conditions in which these satellites function to avoid launching into hazardous solar storms. Secondly, space weather is a crucial component of space situational awareness, recognizing that space is now a warfighting domain, and operational assets are dependent on space for navigation and communication.

Dr. Mozer subsequently discussed DoD's involvement in the operation of various space monitoring and weather-related satellites, including the Defense Meteorological Satellite Program (DMSP). He pointed out that the DoD continues to employ space-based sensors like Energetic Particle Devices to gather situational awareness data and operate ground-based systems, like the Space Environment System and Solar Optical Networks. He then discussed the importance of partnerships for the USSF. As the USSF is relatively small, with around 17,000 personnel, it heavily relies on partnerships with other organizations like NOAA, NASA, and NSF to fulfill its space weather needs. They collaboratively address identified gaps in capabilities for environmental monitoring, including space weather concerns. Dr. Mozer noted the partnership exists between the USSF and NOAA for the COSMIC-2 and Space Situational Awareness Environmental Monitoring (SSAEM) programs. This collaboration provides critical data for space weather modeling and contributes to the broader Space Force unified data library.

To modernize how space weather data is dealt with, the USSFis developing the Space Force Environmental Toolkit for Defense (SET4D), a cloud-based system tailored to specific mission systems. This tool aims to provide rapid and precise anomaly resolution in times of conflict or uncertainty. Internationally, the Space Force partners with allies and various defense ministries to engage in space weather-specific research and fill the gaps in capabilities. Dr. Mozer wrapped up his presentation by stating that USSF is actively involved in space weather research and operations, acknowledging its significance for operational satellite systems and space situational awareness. He reiterated that the Space Force values partnerships with organizations like NOAA and international allies to meet its space weather needs and continue evolving its capabilities for future challenges.

Dr. Jennifer Gannon, Vice President of Research and Development, Computational Physics, Inc.

Dr. Gannon opened her presentation by stating that she was representing the commercial sector, particularly small businesses involved in space weather like CPI. She expressed excitement about the PROSWIFT Act, which aims to address space weather hazards. She remarked that the US commercial space weather industry already contributes significantly to space weather efforts

through government contracts, collaborations with federal agencies like NSF and NASA, and internal development efforts. She highlighted commercial sectors involvement in the American Commercial Space Weather Association (ACSWA), which supports private sector organizations engaged in space weather research and infrastructure development. She pointed out that the commercial sector is estimated to have around 500 full-time employees across 37+ companies, covering various space weather domains from the Sun to the Earth's surface. She indicated that ACSWA members are participating in national committees established by PROSWIFT, like the Space Weather Advisory Group and the National Academies Space Weather Roundtable, demonstrating the commercial sector's growing presence in space weather activities.

Dr. Gannon also mentioned the commercial sector's interest in NOAA testbed activities and the potential contributions of small companies with alternative solutions in areas such as satellite charging, drag, and aviation. She observed that the commercial sector sees itself as essential data providers, especially in ground-based observations like magnetic field data, radars, spectrometers, and more. Dr. Gannon stressed the collaboration between the commercial sector and NOAA to validate operational data streams showed promising results, significantly improving modeling capabilities and emphasized the distinct requirements for operational data streams, such as reliability, low latency, and data quality. She concluded her presentation by mentioning that the commercial sector is thriving and excited about their involvement in PROSWIFT activities and is looking forward to continuing collaborations with federal partners to enhance space weather understanding and forecasting.

PROSWIFT Panel Discussion

Q: What outreach activities are each of the organizations doing to better inform the public about space weather? And how much of a priority are those activities within organizations?

- Ms. Parker: As a part of our user engagement strategy, we are having a significant focus on expanding how we are defining who our user community is, which is not the standard. Just within NOAA, it is not only the Space Weather Prediction Center. We are engaging with many different industries. But beyond industries, we are involved in user engagement down to the public level. It's a part of our user engagement strategy. We are trying to roll that out more actively and proactively in the next 12 months or so. We've done multiple user engagements at different types of workshops, everything from AMS to space weather forums, to reaching out to industry in their industry forums like in the aerospace industry in the telecom industry. We are open to new ideas of how we can reach out to others, but like I said in my discussion, reaching out to the general public and making them informed of how this impacts their day to day lives is very key. And NOAA is expanding that type of user engagement and trying to get feedback on how we can improve on that.

Q: The commercial sector contributions are vital to building a space weather resilient nation. What are the major challenges the commercial sector faces ensuring that their contributions can be integrated into national goals to build the space weather ready nation?

- Dr. Gannon: Using some of the models and making those models and the data available for comparison and for use alongside some of the federal models could be very useful. Participation in the testbed exercises, for example, where we can see if some of the

commercial sector models could really augment federal capabilities would be one way to validate and to move some of the processes forward.

Q: The DoD shares many overlapping interests in research, observations, and predictions in space weather with the science agencies. How are the agencies working together with the DoD to achieve these common goals?

- Dr. Mozer: The DoD has been involved in basic and applied research for space weather for many years, although the funding for such things has gone down. So, we're increasingly needing to cooperate. A lot of that comes from places like the Office of Naval Research, the Air Force Office, scientific research within the DoD, National Science Foundation, and I think there is a community of researchers and practitioners in space, who interact very well together. I used to be the director of the Space Weather Center of Excellence at Air Force Research Lab, and I know we have partners across all funding organizations for basic and applied research, including internationally. I think there is a strong grassroots level tie in across the board and basic and applied research.

Session 2: Recommendations of the Space Weather Advisory Group

Dr. Tamara Dickinson, President, Science Matters Consulting and Chair, Space Weather Advisory Group

Dr. Dickinson opened the session by introducing the Space Weather Advisory Group (SWAG) members serving on the panel:

- Dr. Seth Jonas, Principal for Space Strategy, Development, and Science, Lockheed Martin Corporation
- Dr. Jennifer Gannon, Vice President of Research and Development, Computational Physics, Inc.
- Dr. Delores Knipp, Research Professor, University of Colorado, Boulder
- Dr. Rebecca Bishop, Principal Scientist, The Aerospace Corporation

Dr. Dickinson described the history of the SWAG, which consists of non-governmental end-user representatives, commercial sector representatives, and academic community representatives. The SWAG is chartered with advising the SWORM in response to frustration over the lack of community participation in the development of the first National Space Weather Strategy and Action Plan in 2015. SWAG has provided input for the updated plan in the form of a report that draws from white papers prepared for the Decadal Survey on Solar and Space Physics 2024-2033, National space weather policies and statuses, and broad community input from a series of speakers, panels, and public comments during a hybrid meeting in January 2023. The report, Findings and Recommendations to Successfully Implement PROSWIFT and Transform the National Space Weather Enterprise, was released to the public in April 2023. Dr. Dickinson stated that the 25 findings and 56 recommendations contained in the report are meant to be considered as a whole and, if implemented, will provide the funding, processes, support, and structure to transform changes across the enterprise. While most of the recommendations are not prioritized, the top eleven recommendations are identified.

Dr. Dickinson laid out the following recommendations, while indicating that they are not ranked in order:

1. Fund the federal space weather enterprise
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
3. Ensure OSTP staffing and White House led prioritization and coordination across the national space weather enterprise
4. Protect space weather sensors from spectrum interference
5. Provide long-term support for operational ground-based and airborne sensors and networks
6. Provide and fund critical operational sensors beyond near-Earth
7. Fund NASA missions that advance fundamental science to support space weather research; some recommendations aimed at particular agencies and some across agencies
8. Coordinate benchmark development or improvement with industry
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
10. Support coordinated applied research within the thermosphere (above 100 km altitude), which is critical for space traffic coordination
11. Foster and lead a global space weather enterprise

As next steps, Dr. Dickinson emphasized that the SWAG is looking forward to engaging with the SWORM agencies, other stakeholders, and Congress to discuss the findings and recommendations from the report. The SWAG is also working to provide additional input on resilience focused actions and other needs of end users through the forthcoming results of the user-needs survey SWAG is currently conducting.

Q&A

Q: The power sector noted that a key need was magnetometer data (SWAG rec 6.1?)

- Dr. Gannon: Power utilities need local information, even though space weather is global. It is cost-effective and timely to use resources already in place to augment existing federal resources.

Q: How much did you delve into radio frequency monitoring?

- Dr. Gannon: We did not delve into prioritizing need or what frequencies are most important. Like terrestrial weather, there needs to be some protection so we can continue to monitor. Many types of instruments will have an impact on space weather forecasting, we just need to be aware fully of potential spectrum interference.

Q: Operational community has not prioritized recommendations in the report. How are you handling this lack of prioritization?

- Dr. Jonas: We agree. SWAG recognized there will be a need to prioritize to drive resource allocation (where to invest first); left this to the government

- Dr. Knipp: For ground-based systems, prioritization should come from operational end-users and SWPC
- Dr. Bishop: Need data to be made public.

Q: There is a big gap in R2O2R. I don't see that called out in priorities. Can you identify where R2O fits into the applied research effort?

- Dr. Bishop: Called out in finding 24; specifically, as applied to space traffic coordination. Also, we called out the strong need for testbed activities, and we understand there is more to come for the testbed. These kinds of activities are needed to sort out the uncertainty and variability within the thermosphere
- Dr. Jonas: See report recommendation 2.3 – it talks about possible linkages in OAR function and this effort.

Q: Efforts across government and mainly industry to mitigate a big black-out event

- Dr. Gannon: A lot of work is ongoing, including power sector system vulnerability assessments. We are unable to predict when the impact is and there is not enough time to prepare/mitigate; including not understanding local dynamics. There needs to more data; doing the best it can with data it has, and putting data out for the public
- Dr. Jonas: From DoD perspective, SWAG will be assessing the extent to which there are additional needs across end-user groups. This will allow a closer look at overall resilience stance (both mitigation and response).
- Dr. Knipp: On SWAG user survey, will look at commercial applications that don't talk about space weather, but have systems that could be useful. What we really need is to identify, end-to-end, what the sensitivity of their system is to SW. For example, sectors that rely on GNSS, need to understand what level of resiliency they need in their systems
- Dr. Dickinson: Survey this summer will cover seven sectors: power; emergency management, GNSS (4 parts), SSA, STM, Research, Human Spaceflight, Aviation

Q: Sustainability issues for both ground- and space-based assets

- Dr. Gannon: There is a wealth of ground-based facilities that are reaching end of life; they are relatively cost-effective. SWAG recommendations did address this, noting there needs to be not only continuity but a new paradigm. Some of this should depend on whether they are research instruments or for operations. Recommends NOAA as the lead operational agency to help prioritize.
- Dr. Knipp: In addition to ground-based facilities, we also need long-term continuity of datasets for use by researchers and forecasters

Q: Spectrum issues – we recognize difficulty in regulation of RF spectrum; the end-user engagement with telecoms specifically. How can we work more collaboratively with our telecom partners to recognize that they are both at risk from this, and we both need to operate in this regulatory structure space?

- Dr. Jonas: This is challenging, even for terrestrial weather:
    - We are developing a campaign to build awareness, both between the space weather community and industry (e.g., telecoms) and internally within organizations (both public and private sector).

    - Need studies that answer: What is the economic benefit of space weather forecasting? What are the economic costs of space weather effects? Studies to date have been done in directional level, and they typically focus on easier to understand players, but we need more focus on things like telecommunications, where a full assessment might not have been done. Studies need to be transparent and publicly available.
    - Risk assessment: Need to also put space weather in the global context of risk. Some companies may be more concerned with other types of risk, therefore space weather needs to be in a format where it can be compared with other risks.

Q: How would we do this risk assessment? Who does it?

- Dr. Jonas:
    - The UK has a National Risk Register and process, with a matrix that shows likelihood of specific consequence. They engage with stakeholders to quantify and populate the matrix. All data is integrated, so societal risks, economic risks, etc. are all examined collectively. Here in the US, we are segmented, e.g., FEMA, USGS, etc.
    - Space weather is underfunded with respect to other risks, but we need to make this point clearly by putting space weather risks up next to others, so we can have an intelligent conversation about how we prioritize all risks and how the commercial sector can help address these risks.

Q: One of the key things missing from this discussion is how we use the observations concurrently with assimilation of observations into our predictive models. Are we making the right investments in using that data?

- Dr. Bishop: SWAG comments on having data available, in usable formats, and assimilation should characterize data based on uncertainty. We are probably going to assimilate more than one type of data, so the interactions and errors that go with those need to be addressed. This takes us to the realm of data science and data analytics and ensuring we have a workforce that is ready to go. We need capabilities in machine learning and data processing, As was laid out in the SWAG report and recent NSF report on infrastructure.

Q: With multiple bodies weighing in on SW, how are these efforts aligned and coordinated?

- Dr. Dickinson: The three main efforts are: (if you put Decadal Survey aside): SWAG, Roundtable, and NASA Space Weather Council. The first two are required by PROSWIFT

Q: How do folks from the greater public contribute?

- Dr. Dickinson: Some meetings have a public comments session. Also, SWAG members represent their communities and can go out to get industry-specific feedback and bring it back to SWAG. Looking for help from academic and government counterparts to find and connect with user communities

Q: Is SWAG user survey a once-off or an ongoing effort?

- Dr. Dickinson: We see it as an ongoing effort, not a one-off. We are tasked with this survey and are interested to see what SWORM will do with these recommendations.

Special Remarks

Dr. Michael Morgan, Assistant Secretary of Commerce for Environmental Observation and Prediction, NOAA

Dr. Elsayed Talaat introduced the distinguished speaker, Dr. Michael Morgan.
Dr. Morgan opened his remarks by emphasizing the significant impact of space weather information and the importance of taking actions based on that knowledge. He highlighted the efforts made by the federal government and industry partners to implement the PROSWIF Act. He stated that NOAA, as the authoritative environmental intelligence agency, is committed to providing critical data and information to various sectors, such as public, private, academic, and research. He mentioned NOAA's work on building a space weather observational satellite architecture, which is being executed in partnership with NASA. He remarked that the partnership between NOAA and NASA has been crucial for the past 60 years in understanding and predicting space weather. The observational data generated from this collaboration is used to protect infrastructure like satellites and the power grid, as well as ensuring the safety of astronauts and passengers on flights. NOAA aims to sustain operational observational assets and explore commercial solutions and academic partnerships to enhance their capabilities.

Dr. Morgan spoke about NOAA's interest in space weather support for space situational awareness. He indicated that the NOAA's Office of Space Commerce is providing critical services to mitigate risks to space-based assets and human spaceflight. This office is developing a data sharing platform that includes space weather data to sustain the space environment and ensure safe and secure space operations. Dr. Morgan acknowledged the increasing threat of space weather, especially as the 2025 solar maximum approaches, which could potentially be the most active in decades. He highlighted the need for resilience and preparedness as we approach the solar maximum and indicated that partnerships and collaborations are essential to becoming a Space Weather Ready Nation in this context. Dr. Morgan closed his remarks by acknowledging that building a resilient nation to space weather requires collaboration across the space weather enterprise and that NOAA understands the value of partnerships and collaborations in achieving this objective.

Spotlight Talks

Session Chair. Dr. Antti Pulkkinen, Director, Heliophysics Science Division, NASA Goddard Space Flight Center

Dr. Antti Pulkkinen introduced the two Spotlight Talk presenters. Dr. Scott McIntosh and Mrs. Tonya Ladwig presented the Solar Cycle 25 Update and Human Space Exploration & Space Weather Effects, respectively. Dr. Pulkkinen noted that he was stepping in as the session chair, since Dr. Jim Spann was not able to attend SWEF as originally planned.

Dr. Scott McIntosh, Deputy Director, National Center for Atmospheric Research (NCAR)

Dr. McIntosh opened his presentation on the ongoing solar cycle, which is nearing its maximum phase, by indicating that the motivation for studying solar cycles lies in the increasing dependence on space infrastructure, susceptible to solar and geomagnetic activity. He highlighted that space weather events can occur at any time, making forecasting essential. He showed that the consensus forecast for the current cycle (Cycle 25) initially predicted a continuation of the Sun's 30-year decline. However, the Sun has exceeded these expectations, showing much higher activity, with a significant number of X and M-class flares compared to the previous cycle.

Dr. McIntosh then introduced what he called the "sun clock," which focuses on the Sun's underlying 22-year magnetic activity cycle, providing insights into the varying epochs of solar and geomagnetic activity. He emphasized the importance of understanding these variations for space technology development and infrastructure management. He mentioned that the ionosphere and thermosphere are currently experiencing energization levels higher than observed during the entire Cycle 24, causing challenges in the private sector, with satellites experiencing deorbiting and fuel consumption issues. While acknowledging that geomagnetic and solar activity tends to increase after solar maximum, he presented the promising results of the new climatological approach for solar weather forecasting. He stated that this approach has shown high fidelity in predicting solar flux, offering valuable insights for space weather forecasting. Dr. McIntosh concluded his talk by emphasizing complexities in forecasting the Sun’s behavior and its implications for predicting Earth’s response to the solar cycle. Despite the uncertainties surrounding solar cycles, he remains optimistic about the progress made in the field.

Q&A

Q: Comprehensive observations from the sun and the polar magnetic fields are critical. What are we still missing from the first principles perspective to better predict the solar cycle strength? What fundamental physics were missing? What are some of the key observations that we are missing?

- Dr. McIntosh: The key word is longitude. The Sun is not flat. It is a sphere that rotates. Coriolis force is important. The Coriolis effect also affects magnetism on the Sun. So, comprehensive observations with the Sun are critical, as well as what the polar magnetic fields are doing, because that seems to be an essential part of this clock that keeps the Hale cycle going. The Hale cycle is like the fundamental mode of the star.

Mrs. Tonya Ladwig, Vice President, Human Space Exploration and Orion Program Manager, Lockheed Martin Space

In her Spotlight Talk, Mrs. Ladwig discussed the intersection of human space exploration and space weather. She introduced Lockheed Martin's involvement in building both the Orion crew vehicle for NASA and the GOES-R satellite series and SUVI instrument for NOAA. She explained that as the Vice President for Human Space Exploration and Orion Program Manager, her responsibilities include overseeing the development and production of the vehicle that will transport astronauts back to the moon and beyond. She emphasized that human spaceflight and

space weather communities need to collaborate to protect hardware and crew from the effects of space weather and radiation. She showcased the Orion crew vehicle and highlighted its capabilities, including its larger size compared to the Apollo crew module, its ability to carry up to four astronauts on missions lasting up to 1,000 days, and its capacity to bring back lunar samples for scientific research.

Mrs. Ladwig stressed the importance of mitigating the risks posed by space radiation on both spacecraft and astronauts. She described the presence of radiation sensors and experiments on Orion to measure and understand the radiation environment's effects. Additionally, she showcased the technology demonstration payload, Callisto, which demonstrated how commercial technology, like Amazon Alexa and Cisco's WebEx, could be used to interact with spacecraft. The presentation also touched on the recent Artemis I mission, which successfully tested the integrated launch and re-entry systems of Orion. Mrs. Ladwig outlined future Artemis missions, including Artemis II, a crewed test flight to orbit the Earth and the Moon, and Artemis III, the first mission to land humans on the lunar surface since 1972. She expressed the need to prepare for upcoming missions around the next solar maximum when particle events are more likely. Mrs. Ladwig concluded by emphasizing the importance of studying space weather and its impact on space missions, particularly as we venture further into deep space. She expressed excitement about Orion's potential as a platform for studying the space weather environment and stressed the need for advanced space weather forecasting and now-casting to ensure astronauts' safety during future missions.

Q&A

Q. Thinking about the ultimate transit to Mars, what are some of the unique challenges we will face and what are some of the key gaps that we still need to address?

- Mrs. Ladwig: One of the biggest challenges is propulsion, because Mars is a lot farther away, and astronauts have to be on crew for that much longer. The biggest concern from a space weather perspective would be what are the implications of the space weather in that environment and what additional things do we need to protect for because we really don't know yet. Also, as we start to look at the infrastructure for the moon and for Mars, all the in-situ resources are needed. You can't pack all of that with you on that journey. How do we create some of those resources and those consumables that we need? I mentioned earlier, the service module that is our consumables, but we have a finite amount of consumables with us. So, we must address how we can make additional space for those consumables or also generate them going forward.

Q. A lot of us have been engaged in developing benchmarks to try to get a sense for “how big is big” in our space weather measurements. The spacecraft and astronauts are susceptible to exposure to energetic particles and so are the sensitive electronics that are vulnerable to these energy particles. How do you assess what you have to protect against? What is your benchmark, your thresholds?

- Mrs. Ladwig: There are several benchmarks that we have from industry, e.g., having radiation hardened components for spacecraft. I ran the GPS programs in mid Earth orbit, where there is significant radiation, so everything had to be radiation hardened. We use some of those benchmarks is the baseline when we are looking at human spaceflight and

deep space. But we also looked at redundancies, like our flight controller modules, of which we have four. So, if anyone gets a hit and it gets taken out, we have that redundancy on our spacecraft. So that is how we really address a lot of the possible radiation implications.

Q. Will the radiation data from Orion be made publicly available to the research community?

- It will be made available, once the data is ready for public dissemination.

Session 3: Space Weather Planning and Preparedness: Government Perspective

Session Chair: Lt. Col. Omar Nava, Chief, Space Weather and Environmental EM Effects, USAF/A3WX

Lt. Col. Omar Nava opened the session by introducing the two panelists, Mr. William Murtagh and Mr. Matthew Payne.

Mr. William Murtagh, Program Coordinator, Space Weather Prediction Center, NOAA

Mr. Murtagh began his talk by highlighting the importance of the partnership between NOAA's SWPC) and the Federal Emergency Management Agency (FEMA). The two have worked together to build resilience against space weather impacts by ensuring that key information is delivered to key people in a timely fashion. He spoke of FEMA's key role in disseminating information to federal, state, and local emergency management partners through their operations center to mitigate potential serious impacts on critical infrastructure. In addition to FEMA, Mr. Murtagh also discussed several other key partners who rely on SWPC to communicate timely space weather information to avoid critical impacts, including the North American Electric Reliability Corporation (NERC), the US Air Force 557th Weather Wing, NASA's Mission Control and Space Radiation Analysis Group, the US Department of State, the US Department of Agriculture (USDA), and the White House.

Mr. Murtagh announced that this summer the USDA will be conducting a space weather exercise. To communicate the magnitude of space weather events SWPC uses several storm scales. Mr. Murtagh described how these scales are being updated for the first time since their development over 25 years. The effort to update these scales will take several years and will rely on input from across the community, including not only government stakeholders but industry, academia, and international partners as well. Mr. Murtagh went on to describe efforts to engage state and local emergency response managers in space weather preparedness. The federal response to space weather has been a major area of focus at White House and within the various departments and agencies. States and local emergency managers are now implementing emergency response plans that include space weather into mitigation strategies. Mr. Murtagh indicated that furthering these developments will involve education. This education is being provided at emergency management conferences, through exercises, and by outreach to local weather forecast offices. Mr. Murtagh concluded with a discussion of communication strategy discussions undertaken between the Department of Commerce, Department of Homeland Security, and the National Security Council in March of last year. The major takeaway was that

clear messaging is key, which can be complicated by social media. The need for official channels to inform the public and temper inevitable misinformation is crucial.

Mr. Matthew Payne, Deputy Assistant Administrator for Response, Office of Response and Recovery, FEMA

Mr. Payne echoed Mr. Murtaugh's remarks about the relatively short history of the collaboration between the space weather community and the community of emergency managers. Emergency managers began to turn their attention to space weather following Executive Order 13744, which established the policy of the US to prepare for space weather events to minimize the extent of economic loss and human hardship. This executive order prompted the creation of the Federal Operating Concept for Impending Space Weather Events, which coordinates federal assets and activities to respond to impending space weather events. Mr. Payne described the routine process that has taken shape, in which SWPC participates in operations briefings to facilitate regular monitoring and praised SWPC as a partner. When a space weather event arises, FEMA gets notifications through their operations center, and, depending on the thresholds that are reached, will convene agency leadership teams to discuss the potential impacts with very short timelines. SWPC will brief the relevant regional, state, tribal, and territorial partners on the anticipated timeline and potential impacts.

Mr. Payne indicated that advanced warning to \preposition resources and sufficient information about the location of the impacts is key; however, FEMA is accustomed to working with uncertainty. Mr. Payne stressed the importance of raising awareness throughout the community, so that emergency managers can be on alert looking for cascading impacts to critical infrastructure, healthcare, water, and other resources. With increased education and outreach, space weather impacts can become part of the routine emergency management response preparations. Mr. Payne further described FEMA's role in delivering immediate emergency assistance if critical lifelines communities rely on cannot be ensured at a local level. He described the potential impacts of a large-scale space weather event, where prolonged power outages could significantly impact delivery of services across government. Mr. Payne also described the critical role of clear and consistent communication during an emergency. The National Joint Information Center is a mechanism used to bring the whole of the government together to coordinate communications about the incident. Using established mechanisms ensures that subject matter experts from SWPC or others are getting their messages out and amplified. Mr. Payne closed by stressing that, although the relationship with the space weather community is new, great strides are being made to develop and mature the Nation's ability to respond to these types of incidents in the future.

Q&A

Q. The National Weather Service has terrestrial weather scales similar to the space weather scales. Some are based on impact, and others are based on intensity. In your talk you mentioned impact. There is a difference: Intensity scales are mostly derived from physics; Impact scales are determined by mapping to impacts. The tornado scale is an impact scale. Originally, the hurricane scale was all based on wind and did not account for storm surge. As you consider

redefining the scales, I recommend that you define exactly what you are talking about. Impact scales are fine for certain decision processes, but a real impact scale will connect to how people are going to manage that against decisions they will make that impact society.

- Mr. Murtagh: This amplifies the message about the challenges we face. Geomagnetic storms are a good example. One scale that provides service for many people works well for some and not others. We must define a process where we give notifications letting people know something is happening, and then distribute it to the various sectors so they understand impacts. We cannot have 10 different scales.
- Mr. Payne: Much will go toward actions we are trying to drive through the approach that is used. The focus is on how we make sure the community we are trying to drive understand difference and drive towards the right actions based on communications provided.

Q. As FEMA is developing exercise scenarios for hurricanes, forest fires, etc. Do you bring in space weather as an overlay on top of other disasters?

- Mr. Payne: More recently there have been examples of this. Will drive testing of power outage incident annex and plan for large scale power failures. It is a useful element we can fold in. This hasn't happened consistently because space weather is one of the less common hazards for us.
- Mr. Murtagh: We got a real-world example of this during the 2017 September/October Hurricane season. We had a couple of major category 5 hurricanes in the Caribbean and at just the wrong time, and we got some large flares that affected communication capabilities. In a bad scenario, we can have a space weather event just when emergency responders are relying on backup communications. This demonstrated the usefulness of any exercise having injects like space weather. Another example could be hot shot jumpers responding to a forest fire finding that their satellite phone is not working at the wrong time. The result could be very significant.

Q. The technologies that you use to facilitate disaster response and keep government functioning are sometimes impacting during space weather events. What steps are you taking to mitigate the risk of technology failures resulting in a failure to respond?

- Mr. Murtagh: The coronagraph is an instrument that we rely on to detect CMEs and determine when it occurs, what direction it is going, and how fast it is traveling. But if an energetic particle event occurs at the same time, we refer to the image as a snow storm. You can't get the CME information from that image. The ACE spacecraft measuring the solar wind parameters gets saturation during big storms. We are recognizing some of those vulnerabilities, and the future L1 instruments will not suffer that saturation and loss of information. We identify these vulnerabilities and engineer as best we can around them.
- Mr. Payne: We are regularly practicing what happens if we lose those capabilities. We have binders at each site to hand-write those orders and we use fax machines, which some people had never seen before. We have to go back to low tech options and make sure we can use AM radio if we need to. We recognize this from the space weather side, but also the cyber security side.

Session 4: Space Weather Planning and Preparedness: Industry Perspective

Session Chair: Mr. Bill Murtagh, Program Coordinator, Space Weather Prediction Center, NOAA

Mr. Murtagh introduced the session by describing its theme, which was planning and preparedness for space weather from an industry perspective. He mentioned that while the previous sessions dealt with the coordination between government agencies, SWPC is also actively working to share space weather information with the industry partners and key end users. This session included speakers representing key industries impacted by space weather. The session speakers included three distinguished guests: Captain John Dudley from American Airlines, Mr. Joe Woomer, Senior Vice President of Electric Transmission from Dominion Energy, and Dr. Cathy Drager, the Statewide Director of the University of Minnesota Regional Sustainable Development Partnerships.

Mr. John Dudley, Managing Director, Flight Operations, American Airlines

The topic of Mr. Dudley's presentation was on aviation safety at American Airlines in relation to space weather. He noted that aviation safety has a long history of risk mitigation, mentioning specific areas such as turbulence prediction, volcanic ash avoidance, and 5G transmission effects. He addressed the growing importance of understanding space weather's impact on aviation, outlining potential risks, including communication disruptions, GPS issues, and critical hardware and software failures. Mr. Dudley reminded the audience that the consequences of space weather events can affect not only operational control and navigation, but also the safety and comfort of passengers. His presentation also touched on the American Airlines' training programs for pilots and dispatchers concerning space weather threats and how space weather data are incorporated into airline's flight planning and operational decision-making processes.

Mr. Dudley stressed the importance of collaboration between the aviation industry and space weather experts to develop impact-based products and tools, including graphical representations of radiation dose rates, HF communication disturbances, etc., as well as extended forecasts beyond 24 hours to improve operational decision-making and risk mitigation strategies. The importance of accurate space weather models designed specifically for aviation needs also came up, as a one-size-fits-all approach may not be suitable for aviation operations at various altitudes and latitudes. He noted that a tailored space weather model would provide more reliable and precise information for flight planning and execution. Mr. Dudley concluded his presentation by encouraging collaboration between the space weather community and the airlines to enhance safety measures and further develop the aviation industry's safety management system.

Mr. Joe Woomer, Senior Vice President, Electric Transmission, Dominion Energy Inc.

In his presentation, Mr. Woomer discussed the electric grid's resilience during potential solar flares or other disruptive events. He highlighted the distributed nature of the grid, with metal structures acting as antennae across the system. He mentioned Dominion Energy's infrastructure in Virginia and North Carolina, comprising over 50,000 structures, most of which are metal,

enhancing the grid's ability to withstand disturbances. He stressed the significance of preparing for solar flares, as illustrated by a graphic showing the potential impact on the grid's magnetic field. He compared the electric industry's approach to the airline industry's risk-averse attitude, emphasizing the need for safe, reliable, affordable, and environmentally friendly energy delivery. His presentation delved into the possible consequences of a solar flare interacting with the grid. He mentioned issues like failure of legacy relays, current transformer saturation, and modulation of voltage in the area.

Mr. Woomer also discussed harmonics and noise in sine waves, which can disrupt customer services, communication, and data centers. He noted that the worst-case scenario involves a total voltage collapse due to geomagnetically induced currents impacting high-voltage transformers' magnetic cores. To counter these challenges, utility companies have taken steps to reinforce the grid's resilience. He highlighted the redesigning of high-voltage transformers in the early 2000s, introducing non-conductive bracing to prevent voltage collapse during a solar flare event, as examples of developing resilience. The result of this overhaul was increased confidence that the current infrastructure can withstand expected solar flare impacts, up to a certain level.

Mr. Woomer then described Dominion Energy’s state-of-the-art Real-Time Digital Simulation (RTDS) for testing their protective equipment before deployment in the field. He also described a new high-voltage test lab being built for root cause analysis in the event of equipment failures. It was noted that data sharing and monitoring are critical components of grid resilience. Dominion Energy employs Hall effect current transformers at strategic points along the transmission system to measure DC current. Synchrophasor streaming devices provide terabytes of data to the system operating center and a separate center is being developed to streamline data monitoring and analysis. He expressed a keen interest in sharing this data with the community. The presentation also highlighted a groundbreaking test conducted in collaboration with PJM, involving a live simulation of induced DC current on transformers during a low-load period. The results showcased the success of Dominion’s transformer design implemented after the 1989 event, validating its resilience to solar flare-induced DC currents. Mr. Woomer concluded his presentation by expressing his high confidence in the grid's ability to withstand solar flares and other disruptions. He stressed Dominion Energy’s commitment to preparedness, ensuring the delivery of reliable and uninterrupted service.

Dr. Kathryn Drager, Adjunct Assistant Professor, Statewide, Directory, Regional Development Partnerships, University of Minnesota

In this presentation, Dr. Drager, who is a soil scientist and agronomist from the agricultural sectors, discussed the potential impacts of space weather on agriculture. She emphasized the under-studied nature of this field and the increasing reliance on technology in farming practices. GPS and GNSS technologies have become crucial tools in modern agriculture, enabling precision farming and efficient supply chains. Her presentation showed examples of how disruptions in supply chain during the COVID-19 pandemic led to severe issues in the meat processing system, resulting in the euthanizing of animals due to transportation bottlenecks. The experience of the pandemic highlighted the vulnerability of the global food supply system and the need to develop strategies for better resilience. She outlined a four-part strategy to address supply chain bottlenecks during disruptions: pulling food into households, fortifying existing

assets (e.g., meat processors and grocery stores), creating direct farm-to-grocery supply chains, and exploring regional supply chain options like backhauling.

Regarding space weather's impact on agriculture, Dr. Draeger raised several questions, including how farmers will operate without GPS if they lack prior skills and expertise to adapt, and how the industry can prepare for severe events like a Carrington Event, which could cause substantial disruptions. She stressed the importance of defining the range and duration of potential space weather impacts on agriculture, considering both geographic regions and the type of crops produced and advocated for developing alternative distribution and supply chain options, as well as leveraging existing assets and infrastructure to enhance resilience. It was noted that the Cooperative Extension System, which operates across the United States, could serve as a valuable asset to educate and prepare farmers for space weather-related disruptions. Dr. Draeger suggested creating a module on space weather within the Extension Disaster Education Network (EDEN) to raise awareness and foster preparedness. In her concluding remarks, Dr. Draeger highlighted the need for further research and preparedness in understanding space weather's potential impacts on agriculture. She emphasized the importance of developing strategies to enhance the resilience of the agricultural sector in the face of possible disruptions, both at the local and national levels.

Q&A

Mr. Murtagh mentioned that the 2019 FEMA threat and hazard identification and risk assessment document identified two natural hazards that could impact at a national scale. One was Space Weather, and the other one was pandemic.

Q. It is my understanding that most precision GNSS users, if they are aware of a space weather impact to the accuracy of the system, will pause operations. But a community that is not aware enough of this impact, instead of pausing and delaying, is planting seeds in the wrong spots. Is this the current state of affairs for the precision agriculture sector?

- The impact of space weather on agriculture would definitely be time-specific. There are certain time windows that would be much more detrimental than others. You can harvest without GPS, because you can see where the corn is down or what you've taken in. It's much harder to plant without GPS. Another example is people who are trying to do field trials. If they encounter space weather and don’t account for it, it messes up their field trial, which then equals a missed year of research. We need more awareness in the community about space weather and its impact on their GPS systems.

Session 5: Moving Forward Towards a Space Weather Resilient Nation

Mr. Craig Fugate, former director of FEMA

Mr. Craig Fugate opened the session by describing the potential impact of an extreme space weather event as being analogous to either the Y2K scare or the COVID-19 pandemic. In the case of Y2K, there was a lot of fear and anxiety around the scale and scope of the potential impacts, but ultimately the negative impacts were not realized. On the other hand, a lot was

known about the potential impacts of a global pandemic prior to the COVID-19 pandemic; however, there were extreme outcomes that were not anticipated. Mr. Fugate emphasized that we have made great strides in understanding space weather impacts, but at the same time, technology has also advanced and become increasingly interconnected. The Global Navigation System Satellite (GNSS) constellations used for precision navigation and timing applications have grown both in the number of available satellites and applications and dependencies where downstream impacts are not well understood.

Mr. Fugate stressed that additional complications could arise, because geomagnetic storms may not occur in isolation on a "blue sky" day. They can coincide with other hazardous events like extreme weather and impact technologies that have not been tested. Even the power grid, where significant effort has been put toward understanding and preparing for space weather impacts, has changing technologies like bidirectional charging, battery bank storage, and microgrids. He recounted former President Obama's approach to disasters by identifying what are the things we can live without and those we cannot. Mr. Fugate reiterated the need to look at impacts to our changing vulnerabilities. He identified two approaches for protecting crucial components of our infrastructure and those vulnerable technologies: incentivizing risk reduction and regulation. Mr. Fugate closed his remarks by reminding the audience that in his line of work the unknown risks are the most concerning. Although we know a lot about space weather, we have never been through a large-scale event, like a Carrington event, with our current technology.

Dr. Tamara Dickinson, President, Science Matters Consulting, Chair, Space Weather Advisory Group

Mr. Fugate asked Dr. Dickinson to describe what resilience against space weather impact looks like to her. Dr. Dickinson described what she sees as the most easily attainable recommendations to the SWORM agencies outlined in the SWAG report. These include operational suggestions like implementing more Cooperative Research and Development Agreements (CRADAs), Memoranda of Understanding/Agreement (MOU/MOA), and more transparency and reporting. Another recommendation obtainable in the near term is to implement more ground-based observations. Looking further, Dr. Dickinson highlighted the issues with funding and the need for advocacy among the community to address those issues. Another longer-term suggestion from the report is to ensure the sustainability of both ground-based and space-based measurements. She praised the steps NOAA has taken toward this goal with the Space Weather Follow On (SWFO) and Space Weather Next programs, but also stressed the need to keep going. Additionally, Dr. Dickinson described the need for updated benchmarks and scales for describing space weather impacts and the continued need for industry involvement in defining unified benchmarks. She mentioned that the ongoing SWAG user survey can help here by providing a chance to reach out to sectors that need some additional education to participate in these efforts. Dr. Dickinson also highlighted the need to understand the impact of cascading risks when disasters coincide with one another. She closed by discussing the need to look beyond near-earth space weather impacts as we expand our reach in space to the Moon, Mars, and beyond.

Dr. Delores Knipp, Research Professor, University of Colorado, Boulder

Mr. Fugate asked Dr. Knipp what we need to build a future resilient to space weather. Dr. Knipp described her perspective as coming from a research and teaching background in an aerospace engineering science department at a university and focused on the near-Earth space environment, particularly in low earth orbit (LEO). She recounted five instances since the United States became a spacefaring nation where the North American Aerospace Defense Command (NORAD), tasked with tracking and cataloging space-based objects, lost the ability to maintain their catalog. As the number of satellites and objects in space grew, each subsequent event had a greater impact and prolonged time to recover the catalog. Dr. Knipp described the recent 2022 Starlink incident, in which several satellites were lost during orbit raising due to increased drag in the thermosphere because of a moderate geomagnetic event. She highlighted the upcoming satellite environment testbed experiment that SWPC will hold in the fall of 2023 and the need to get the stakeholders together to address the outstanding questions surrounding satellite drag environment needs. Dr. Knipp called special attention to the need to encourage development of the processes for incorporating new data types and observations into models that can assimilate them. This involves understanding the uncertainties in the observations themselves and in the poorly characterized processes in the models. She stated the importance of these advances for modeling the drag environment, particularly at low altitudes where the Starlink incident occurred. She closed by emphasizing the SWAG recommendation that additional resources are needed to understand the low earth environment.

Mr. Mark Lauby, Senior Vice President and Chief Engineer, North American Electric Reliability Corporation (NERC)

Mr. Fugate praised the work done by the North American Electric Reliability Corporation (NERC) to understand space weather impacts on the power grid and asked Mr. Lauby what are the next steps. Mr. Lauby emphasized voltage collapse as the largest concern for the power grid and the vulnerability that caused the Hydro-Quebec outage in 1989 that lasted for nine hours. Mr. Lauby described the steps taken to address the space weather impacts on the power grid. A set of standards was developed taking into consideration two time frames. The first is the operating time frame, which starts once an alert from NOAA is received, at which time grid operators start to preposition their systems to mitigate the risk. The second time frame is long-term, in which you design the system to withstand certain thresholds of impact. Mr. Lauby said that these two standards work together to create a more resilient system. He described NERC's ongoing work to continue to understand geomagnetic disturbances, including an upcoming workshop in April 2024. Further advances include system design and tools such as the three-phase model currently in use.

Mr. Lauby also cited efforts to collect data on geomagnetically induced currents (GIC) to help researchers better understand effects on the power grid. Further, he cited NERC's role in supporting SWAG through staff and collaboration with SWPC to prepare for the upcoming maximum phase of the solar cycle. Looking ahead, Mr. Lauby stated that one of the challenges his industry is facing is a changing mix of resources used for electric power as well as the trends toward decarbonization, digitization, and decentralization. The implications of these new resources on inverters are not well understood. Additionally, Mr. Lauby stressed the need for improved space weather forecasting capabilities to maintain resilience in the power grid in the years to come. He mentioned that the power grid accounts for 7-10% of the US economy, but

every other sector depends on the availability of electric power. He stated that this dependency will only increase in the future. He closed with a further recommendation to ensure a resilient power grid with additional monitors and higher fidelity data from ground-based magnetometers to enable simulations.

Mr. Clinton Wallace, Director, Space Weather Prediction Center, NOAA

Mr. Fugate asked Mr. Wallace what NOAA's SWPC needs to do to continue supporting the needs of their customers for space weather forecasts. Mr. Wallace described his background, in which he transitioned from working on terrestrial weather to space weather within the National Weather Service. This move prompted a shift in his expectations regarding predictive capabilities of space weather models. There is much greater uncertainty in space weather predictions and thus a need to communicate that uncertainty effectively.

To address SWPC support, Mr. Wallace first cited the need for basic research to improve the forecast products SWPC customers rely on. NOAA does not currently have a component dedicated to basic research as it does for terrestrial weather. Mr. Wallace also identified a more mature research to operations and operations to research capabilities. SWPC is making strides in this area by building a space weather prediction testbed to bring together the stakeholders and facilitate collaboration. SWPC conducted a successful aviation testbed exercise in September of 2022, and hopefully this success will be repeated with the testbed exercise planned for low earth orbiting satellites in fall of 2023. Finally, Mr. Wallace described what improvements in communication could help to support customer needs going forward. The work to revise the scales used to quantify the magnitudes of space weather events described earlier in the forum and can translate to better products and services to support decision makers. There is a tangible need to integrate social, behavioral, and economic sciences into the development and transformation of products and services. This would ultimately help enable decision makers to understand the uncertainty and ensure they have actional information to support their decision process.

Mr. Brent Blevins, Subcommittee Staff Director, US House Committee on Science, Space, and Technology

Mr. Blevins discussed the steps the space weather enterprise and policy makers need to take to build infrastructure resilient against extreme space weather. He described the need for legislators and their aids to listen to the experts in various fields, including space weather. This would enable relevant understanding and highlight what steps the legislative branch needs to take and what needs to be delegated to the executive branch. Congress does succeed in performing a coordinating function either between different executive branch agencies or between constituent groups, for example academia and industry. This coordination effort can be achieved either through legislation or oversight of the executive branch. When the PROSWIFT Act was a bill, Mr. Blevins and his colleagues in the House Committee on Science, Space, and Technology strived for balance between authorizing activities and allowing the executive branch agencies to work. Passing a bill into law was just the first step in the process, and often that is the easiest step. Once the bill is signed, the implementation begins, and the committee checks on the progress of the implementation through briefings from the agencies as well as informal

conversations to ensure progress is on track. The recent SWAG report described in Session 2 will inform what steps legislators take next.

Several other bills are moving through committee now that may impact space weather operations. The first is the NOAA Organic Act and the second is commercial space legislation under consideration prompted by the exponential growth of activities in space. This bill will address how those are managed and what role executive branch agencies will play. Space weather will be a consideration in this proposed legislation. The third bill is the NASA Authorization Act. The NASA Science Mission Directorate has several projects in various stages of their mission lifecycles. One of those is the Artemis mission, which will involve crews going to the surface of the moon for multiple days. Protecting those crews from solar radiation will require coordination among the agencies. Mr. Blevins also mentioned a recent bill that addresses how the Department of Energy works with the NSF and NASA, enabling effective use of resources for radiation modeling and research. Finally, Mr. Blevins briefly mentioned the appropriations bills currently under consideration including the Commerce, Justice, and Science bill that funds NOAA, NSF, and NASA.

Q&A

Q. Many years ago, there were no academic departments in environmental sciences, but the priority was recognized, and now there are departments all over the country. Do we have to get academic institutions more aligned with the educational component necessary for a space weather resilient nation, specifically?

- Dr. Knipp: The NSF funds faculty development opportunities. We need to tackle this issue not just from the top down in terms of faculty, but from the course offerings up. We need to develop material that can either be offered as stand-alone courses or certificates. The Meteorology Department at Millersville University is offering a course sequence on space weather policy. Catholic University has a space weather master's degree. The University of Colorado, Boulder has a four-course space weather sequence resulting in a certificate. We may not be ready to have a stand-alone space weather department, which would need to be justified economically. We are going in the right direction, although very slowly.

Q. What should our outreach to the emergency response community at the state and local level look like? How do we do that effectively?

- Mr. Fugate: In the emergency management world we deal with consequences of events. When I got to FEMA, I asked about the plan for space weather, and many people had not heard of space weather. If you go to the local level, we do not always understand the threat and are unsure of what the consequences are. Through SWAG outreach we have found that some groups are very aware of space weather and can easily be surveyed. The emergency management community is one that needs more education. This can be achieved by reaching out on the federal, regional, and state level and providing them with descriptions of the worst-case scenarios and the timelines and steps they must take to prepare for or address impacts. We work with worst-case scenarios because we want to exercise all of the contingency plans. Communications and power are often impacted. What do we do without these resources? Responses will look different depending on the

location. The response in New York City will look entirely different from Fargo, which will be entirely different from Butte, Montana. When power is out for a few hours, it is an inconvenience. When the outage extends for days, it gets riskier. Beyond that, the situation is more perilous. This can be complicated if we are also dealing with extreme weather, extreme heat, or extreme cold. No single agency owns this. We need observations, forecasting, research, and an understanding of the industries that are impacted. Emergency and risk managers need to understand how much time they have to work, and the uncertainties associated with the information they will receive.

Q. Since there will never get a perfect forecast, uncertainty is an important aspect. Decision makers will have to make their decisions in the face of that uncertainty. How do they make their risk assessment, especially for something they have never seen before and cannot imagine, as is the case for space weather?

- Mr. Fugate: We need to understand where the tipping point is, where we get a decision maker to the point of doing something differently, based on a forecast for an event they have never had before and do not understand. Often, they may have some conflicting information coming in, and that is not an ideal situation for a geomagnetic storm of significant impact. Decision makers need to be in a place where they know the steps they may have to take, and they have the time to take them. As space weather forecasts and our understanding of impacts improve, we need to get the emergency management community to a place where they do something to affect the outcome. There is a fear of overreacting. We understand that the forecast may not be verified, and people may question why seemingly unnecessary steps were taken. I would rather testify on the Hill that I took an action that costs money rather than have the alternative outcome where no action was taken to mitigate the impacts. I would rather be proactive than reactive. We must understand the uncertainty and the consequences if no action is taken. Resilience takes time to build and we must be prepared to work with what we have today. We will hopefully be able to build on that to get to where we want to be in the next ten years.

5. Appendix A – 2023 SWEF Agenda

8:30 AM - 9:00 AM	**Opening Remarks**
	Session Chair: Dr. Elsayed Talaat, Director, Office of Projects Planning and Analysis, NOAA
8:30 AM - 8:35 AM	Welcome from the Organizer - Dr. Elsayed Talaat, Director, Office of Projects Planning and Analysis, NOAA
8:35: AM - 8:40 AM	Keynote Remarks - The Honorable Gary Peters (recorded), US Senator from Michigan, Chairman of the Senate Homeland Security and Governmental Affairs Committee and Sponsor of the PROSWIFT Act
8:40 AM - 8:50 AM	Keynote Remarks - The Honorable Richard Spinrad, Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator
8:50 AM - 8:55 AM	Keynote Remarks - The Honorable Frank Lucas, US Congressman from Oklahoma and Chairman of the House Science, Space and Technology Committee
8:55 AM - 9:00 AM	Keynote Remarks - Dr. Ezinne Uzo-Okoro, Assistant Director for Space Policy, White House Office of Science and Technology Policy
9:00 AM - 10:00 AM	**Session 1: Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Progress**
	Session Chair: Mr. Bill Murtagh, Program Coordinator, Space Weather Prediction Center, NOAA
9:00 AM - 9:10 AM	Update from the United States Geological Survey - Dr. David Applegate, Director, U.S. Geological Survey
9:10 AM - 9:20 AM	Update from the National Oceanic and Atmospheric Administration - Ms. Irene Parker, Deputy Assistant Administrator for Systems, NESDIS, NOAA
9:20 AM - 9:30 AM	Update from the National Aeronautics and Space Administration - Ms. Peg Luce, Acting Director, Heliophysics Division, NASA
9:30 AM - 9:40 AM	Update from the National Science Foundation - Dr. Alexandra Isern, Assistant Director, Directorate for Geosciences, NSF
9:36 AM - 9:48 AM	Update from the Department of Defense - Dr. Joel Mozer, Director of Science, Technology and Research, U.S. Space Force
9:48 AM - 10:00 AM	Update from the Commercial Sector - Dr. Jennifer Gannon, Vice President of Research and Development, Computational Physics, Inc.
10:00 AM - 10:30 AM	**PROSWIFT Panel Discussion**

10:30 AM - 11:00 AM	**Break**
11:00 AM - 12:00 PM	**Session 2: Recommendations of the Space Weather Advisory Group**
	Moderator: Dr. Tamara Dickinson, President, Science Matters Consulting; Chair, Space Weather Advisory Group
	Panelists: Dr. Seth Jonas, Principal for Space Strategy, Development, and Science, Lockheed Martin Corporation Dr. Jennifer Gannon, Vice President of Research and Development, Computational Physics, Inc. Dr. Delores Knipp, Research Professor, University of Colorado, Boulder Dr. Rebecca Bishop, Principal Scientist, The Aerospace Corporation
12:00 PM - 12:45 PM	**Lunch**
12:45 PM - 12:55 PM	Special Remarks - The Honorable Michael Morgan, Assistant Secretary of Commerce for Environmental Observation and Prediction, NOAA
1:00 PM - 1:30 PM	**Spotlight Talks**
	Chair: Dr. Antti Pulkkinen, Director of the Heliophysics Science Division, NASA Goddard Space Flight Center
1:00 PM - 1:10 PM	Solar Cycle 25 Update - Dr. Scott McIntosh, Deputy Director, National Center for Atmospheric Research (NCAR)
1:10 PM - 1:30 PM	Human Space Exploration & Space Weather Effects - Mrs. Tonya Ladwig, Vice President, Human Space Exploration and Orion Program Manager, Lockheed Martin Space
1:30 PM - 2:00 PM	**Session 3: Space Weather - Planning and Preparedness: Government Perspective**
	Session Chair: Lt. Col. Omar Nava, Chief, Space Weather and Environmental EM Effects, USAF/A3WX
1:30 PM - 1:40 PM	SWPC Emergency Management Coordination - Mr. Bill Murtagh, Program Coordinator, Space Weather Prediction Center, NOAA
1:40 PM - 1:50 PM	Federal Emergency Management Agency - Mr. Matthew Payne, Deputy Assistant Administrator for Response, Office of Response and Recovery, FEMA
1:50 PM - 2:00 PM	Q&A
2:00 PM - 3:00 PM	**Session 4: Space Weather - Planning and Preparedness: Industry Perspective** Session Chair: Mr. Bill Murtagh, Program Coordinator, Space Weather

	Prediction Center, NOAA
2:00 PM - 2:15 PM	Transportation Sector - Mr. John Dudley, Managing Director, Flight Operations, American Airlines
2:15 PM - 2:30 PM	Energy Sector - Mr. Joe Woomer, Senior Vice President, Electric Transmission, Dominion Energy Inc.
2:30 PM - 2:45 PM	Agriculture and the Global Supply Chain - Dr. Kathryn Draeger, Adjunct Assistant Professor, Statewide Director, Regional Development Partnerships, University of Minnesota
2:45 PM - 3:00 PM	Q&A
3:00 PM - 3:30 PM	**Break**
3:30 PM - 4:30 PM	**Session 5: Moving Forward Towards a Space Weather Resilient Nation** **Moderator:** Mr. Craig Fugate, Principal, Craig Fugate Consulting **Panelists:** Mr. Mark Lauby, Senior Vice President and Chief Engineer, North American Electric Reliability Corporation (NERC) Dr. Delores Knipp, Research Professor, University of Colorado, Boulder Mr. Brent Blevins, Subcommittee Staff Director, US House Committee on Science, Space, and Technology Mr. Clinton Wallace, Director, Space Weather Prediction Center, NOAA Dr. Tamara Dickinson, President, Science Matters Consulting, Chair, Space Weather Advisory Group
4:30 PM - 4:40 PM	**Closing Remarks and Adjourn**
4:30 PM - 4:40 PM	Closing Remarks - Dr. Elsayed Talaat, Director, Office of Projects Planning and Analysis, NOAA

6. Appendix B – Speaker Biographies

Gary Peters, US Senator from Michigan and Chairman of the Senate Homeland Security and Governmental Affairs Committee

Senator Gary Peters (D-MI) has been honored to represent the State of Michigan in the U.S. Senate since 2015. He has focused on uniting our communities by fighting for the things we all agree on — a stronger economy, good-paying jobs, affordable health care, a secure retirement and an opportunity for everyone to succeed. During the last Congress (2021-2022), Gary authored and was the principal sponsor of 19 bills signed into law – the most enacted into law by a U.S. Senator during a single Congress in over 40 years. He achieved this by building on his record of working in a bipartisan manner.

Peters serves on the United States Senate Committee on Commerce, Science, and Transportation, and is a champion of The Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act, which directs the federal agencies that study and predict space weather to coordinate with the private sector to assess the potential impacts of space weather on the United States, and determine what new research and technology is needed to improve the ability to forecast space weather events and mitigate potential damage. The legislation outlines clear roles and responsibilities for those federal agencies, including the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the Department of Defense (DOD) and the Federal Aviation Administration (FAA).

Frank Lucas, US Congressman from Oklahoma and Chairman of the House Science, Space and Technology Committee

Congressman Frank Lucas is a fifth generation Oklahoman whose family has lived and farmed in Oklahoma for over 120 years. Born in Cheyenne, Oklahoma, Lucas graduated from Oklahoma State University in 1982 with a degree in Agricultural Economics. He was first elected to the United States House of Representatives in a special election in 1994. In the 118th Congress, Lucas serves as the Chairman of the House Science, Space, and Technology Committee. As Chairman, Frank is committed to ensuring that we, as a nation, harness American innovation improving energy efficiency and effectiveness, support research and basic science labs, improve access to STEM education while building the American STEM workforce, and maintain American global leadership in space exploration.

Dr. Ezinne Uzo-Okoro, Assistant Director for Space Policy for the White House Office of Science and Technology Policy

In almost 20 years of U.S. government service, Dr. Uzo-Okoro has developed several national policies and contributed to over 60 NASA missions and programs – as an engineer, technical expert, manager, and executive – in space science and technology topics. At the White House, she leads the aeronautics, space, and manufacturing portfolios, and has released policy on

Aeronautics Priorities, Earth Observations, Orbital Debris, Microgravity research, Space Weather, In-space Servicing Assembly and Manufacturing, and Advanced Manufacturing.
Her 17-year engineering career spanned contributions to earth observations, planetary science, heliophysics, astrophysics, human exploration, and space communications missions, which represent over $9.2 Billion in total program value to NASA. She has an undergraduate degree in Computer Science from Rensselaer Polytechnic Institute, and three masters degrees in Space Systems, Space Robotics, and Public Policy from Johns Hopkins University (APL), MIT (the Media Lab), and Harvard University, respectively. She earned her doctorate degree in Aerospace Engineering from MIT. Her story is profiled in President George W. Bush's book, Out of Many, One.

Dr. Richard Spinrad, Under Secretary of Commerce for Oceans and Atmosphere & NOAA Administrator

Richard (Rick) W. Spinrad, Ph.D., was sworn in on June 22, 2021 as the Under Secretary of Commerce for Oceans and Atmosphere and the 11th NOAA Administrator. Dr. Spinrad is responsible for the strategic direction and oversight of the agency and its over 12,000 employees, including developing NOAA's portfolio of products and services to address the climate crisis, enhancing environmental sustainability and fostering economic development, and creating a more just, equitable, diverse, and inclusive NOAA workforce.
Most recently, Dr. Spinrad served as a Professor of Oceanography and Senior Adviser to the Vice President of Research at Oregon State University (OSU). He was also Vice President for Research at OSU from 2010-2014.
Dr. Spinrad served as NOAA's Chief Scientist under President Barack Obama from 2014 until 2016. He also led NOAA's Office of Oceanic and Atmospheric Research and National Ocean Service from 2003-2010. While at NOAA, Dr. Spinrad co-led the White House Committee that developed the nation's first set of ocean research priorities and oversaw the revamping of NOAA's research enterprise, including the development of the agency's Scientific Integrity policy.

Prior to initially joining NOAA, Dr. Spinrad held leadership positions at the U.S. Office of Naval Research and Oceanographer of the Navy, where he was awarded the Distinguished Civilian Service Award — the highest award given by the U.S. Navy to a civilian. He has held faculty appointments at OSU, the U.S. Naval Academy, and George Mason University; served as Executive Director at the Consortium for Oceanographic Research and Education; was President of Sea Tech, Inc.; and worked as a research scientist at OSU and the Bigelow Laboratory for Ocean Sciences. He also developed the National Ocean Sciences Bowl for high school students. In the international arena, Dr. Spinrad served as the U.S. permanent representative to the United Nations' Intergovernmental Oceanographic Commission from 2005-2009.
He is the recipient of Presidential Rank Awards from presidents George W. Bush and Barack H. Obama. Dr. Spinrad is past president of The Oceanography Society (TOS) and the Marine Technology Society. He is a Fellow of the American Meteorological Society, Marine Technology Society, TOS, and the Institute of Marine Engineering, Science and Technology (IMarEST), and an IMarEST Chartered Marine Scientist.
Dr. Spinrad received his B.A. in Earth and Planetary Sciences from The Johns Hopkins University, and his M.S. and Ph.D. in Oceanography from Oregon State University.

Dr. David Applegate, Director of the United States Geological Survey

David Applegate is the 18th Director of the U.S. Geological Survey, sworn in by Secretary of the Interior Deb Haaland on Aug. 15, 2022. Prior to assuming his official role, he exercised the delegated authority of the USGS Director beginning on Jan. 20, 2021. He served as the Associate Director for Natural Hazards since 2011, leading USGS emergency response activities and overseeing the bureau's geologic hazards and coastal and marine programs. He co-chairs the interagency Science for Disaster Reduction working group and chairs the interagency Civil Applications Committee.

Applegate is a fellow of the American Association for the Advancement of Science and the Geological Society of America and is a past president of the Geological Society of Washington. Applegate joined the USGS in 2004 as the first Senior Science Advisor for Earthquake and Geologic Hazards. Prior to that, he spent eight years with the American Geosciences Institute (AGI) federation of geoscience societies, where he directed science policy and served as the editor of Geotimes, AGI's news magazine for the earth sciences. Applegate has also served with the U.S. Senate Committee on Energy and Natural Resources as the American Geophysical Union's Congressional Science Fellow and as a professional staff member. He has taught at Johns Hopkins University and served as an adjunct professor at the University of Utah. Applegate has a B.S. in geology from Yale University and a Ph.D., also in geology, from the Massachusetts Institute of Technology.

Ms. Irene Parker, Deputy Assistant Administrator for Systems, NOAA

Irene Parker has 20 years of experience in all facets of information technology, security, enterprise architecture, in both public and private sectors.

Mrs. Parker's expertise ranges from leading information technology organizations, managing cyber risks, and implementing science and technology solutions. Currently, she serves as the Deputy Assistant Administrator for Systems for National Environmental Satellite, Data, and Services (NESDIS) which is part of the National Oceanic and Atmospheric Administration (NOAA).

Prior to joining the federal service, she held senior positions at Deloitte Consulting and Accenture. While in the private sector, she was responsible for process engineering, strategic planning, and business development. She received a Bachelor of Science degree in Mathematical Sciences from Johns Hopkins University Whiting School of Engineering in Baltimore, MD and received an Executive Masters in Public Administration from American University.

Ms. Peg Luce, Heliophysics Division Acting Director (NASA)

Peg Luce is the Acting Director of the Heliophysics Division in the Science Mission Directorate at NASA Headquarters. The Heliophysics Division manages a portfolio of space systems and scientific research dedicated to studying the Sun, heliosphere, and planetary environments as elements of a single interconnected system. Prior to joining Heliophysics in 2015, she had served for seven years as the Deputy Director of NASA's Earth Science Division.

Luce joined NASA's Goddard Space Flight Center in 1987 following six years of engineering experience in the private sector. Throughout her career, Luce has been involved in the development of spaceflight systems to support NASA's science programs. At Goddard, she served in a number of leadership roles in the Flight Projects Directorate, including Project Manager for the Earth Observing System Aura Mission, Associate Director of Flight Projects for Project Formulation, and Chief of the Advanced Concepts and Formulation Office. Luce received a Bachelor of Science in Engineering Mechanics from the University of Wisconsin, Madison.

Dr. Alexandra Isern, Assistant Director for Geosciences (NSF)

Dr. Alexandra Isern is the U.S. National Science Foundation assistant director of its Directorate for Geosciences, or GEO. She has spent the last 20 years at NSF serving in various roles within three divisions of the directorate, including leading the Surface Earth Processes and Antarctic Sciences Sections and serving a two-year stint with the National Science Board. Isern had been serving as acting assistant director since June 2021. Prior to that appointment, she served as the deputy assistant director for geosciences and as section head of the directorate's Antarctic Sciences Section, where she led the section in formulating and implementing research objectives and managed administrative, fiscal and personnel issues.
GEO supports basic research that advances the understanding of the global environment through the interdisciplinary study of the atmospheric, Earth, ocean, and polar sciences. Basic research supported by GEO enables preparation for and subsequent mitigation of, or adaptation to, natural environmental hazards such as earthquakes, tornados, hurricanes, tsunamis, drought, solar storms, and other disruptive natural events. As the primary U.S. supporter of fundamental research in the polar regions, GEO provides interagency leadership for U.S. polar activities as well. Isern received her bachelor's degree in geology from the University of Florida, her master's in oceanography from the University of Rhode Island, and her doctorate in geochemistry from the Swiss Federal Institute of Technology, Zurich. Her research primarily focuses on climate-driven evolution of carbonate platforms and reefs and entailed extensive field experience.

Dr. Joel Mozer, United States Space Force Director of Science, Technology and Research

Dr. Joel B. Mozer, a Senior Level Executive, is the United States Space Force Director of Science, Technology and Research, the Pentagon, Arlington, Virginia. He serves as the central lead for all science and technology matters for an organization that comprises approximately 11,000 space professionals worldwide and manages a global network of satellite command and control, communications, missile warning and launch facilities. In this role, he develops long-term military requirements for the Space Force and interacts with other principals, operational commanders, combatant commands, acquisition, and international communities to address cross-organizational science and technical issues and solutions. Dr. Mozer represents U.S. Space Force science and technology on decisions, high-level planning, and policy, building coalitions and alliances throughout the U.S. government, industry, academia, the international community, and other scientific and technology organizations.

Dr. Mozer has more than 30 years of space science, engineering, management, and financial experience working space and ground systems for the DoD. In addition to the Integrated Experiments Division, he served as Chief of the Battlespace Environment Division and led the

laboratory's Space Weather Center of Excellence and was a scientist at the National Solar Observatory at Sacramento Peak. Before arriving to AFRL, Dr. Mozer worked at the Air Force's Radar Attenuation and Scattering facility at Holloman AFB, N.M. where he developed measurement and analysis techniques to study the radar cross section of low-observable aircraft and technology. Prior to that, he worked for the Army's Atmospheric Sciences Laboratory where he developed techniques to quantify the effects of natural and man-made battlefield obscurants on electro-optical sensors.

Dr. Jennifer Gannon, Vice President of Research and Development, Computational Physics, Inc.

Jennifer L. Gannon has been studying charged particles and electromagnetic phenomena in near-earth space and the solid earth throughout her scientific career. Jenn served as a scientist at the NOAA Space Environment Center and its successor agency, the NOAA Space Weather Prediction Center, and later as a Federal researcher at the U.S. Geological Survey. Moving to the private sector, Jenn co-founded Space Hazards Applications, LLC, of Boulder, Colorado, a consulting firm for space hazards to build infrastructure. Jenn is the author or co-author of many publications in the peer-reviewed literature, as well as several U.S.G.S. Open-file Reports and conference presentations. Jenn received her B.S. from the University of Virginia in 2000 and her Ph.D. from the University of Colorado in 2005.

Dr. Tamara Dickinson, President, Science Matters Consulting, Chair, Space Weather Advisory Group

Dr. Tamara Dickinson is the Founder and President of Science Matters Consulting, LLC. She provides professional services at the intersection of science and government to influence national policy and assist organizations to ensure sound science is available to inform policy and management decisions across the Earth, environmental, and space sciences, and disaster and climate resilience fields. Dr. Dickinson currently serves as the Chair of the White House Space Weather Advisory Group (SWAG).

Tamara served as the Principal Assistant Director for Environment and Energy at the White House Office of Science and Technology Policy (OSTP) where she coordinated the Federal Government's activities to better prepare the U.S. for the impacts of climate change, to promote sustainable development, to foster new and cleaner sources of energy, to enable the Earth and space sciences, and to build the nation's disaster resilience. She coordinated and administered the environment, natural resources, and Earth and space science research and development portfolio across the Federal government and integrated their activities with non-governmental, academic, private sector, and international partners. Dr. Dickinson oversaw the National Ocean Council, U.S. Global Change Research Program, and interagency committees on earth observing, air and water quality, disaster risk reduction, space weather, ecological services, toxins, the Arctic and, ocean science and technology.

Prior to working at the Obama White House, Dr. Dickinson led scientific and policy activities, and developed and implemented the National Geological and Geophysical Data Preservation Program and the Geology Laboratory Program at the U.S. Geological Survey. Prior to joining

USGS, Tammy held several positions at the National Research Council, including Senior Program Officer for the Committee on Earth Resources, Acting Associate Director for the National Materials Advisory Board and the Board on Manufacturing and Engineering Design, and Associate Director and Acting Director for the Space Studies Board. She has also held program management and science policy positions at the National Science Foundation and NASA Headquarters.

Dr. Dickinson is a recipient of numerous awards and honors, including the Department of Interior Superior Service Award and Meritorious Service Award, and is a Fellow of the Geological Society of America. Tammy has an asteroid (Asteroid 1981 EU22 Tammydickinson) named in honor of her research and program management work.

Tamara received her B.A. from the University of Northern Iowa, and M.S. and Ph.D. from the University of New Mexico.

Rebecca L. Bishop, Ph.D, The Aerospace Corporation, Principal Scientist Space Science Applications Laboratory

Dr. Bishop holds B.S. degrees in Physics and Mathematics from the University of Idaho and M.S. and Ph.D. degrees in Physics from the University of Texas at Dallas. Her area of specialty is ionospheric physics and utilizing GNSS navigational signals to observe the space environment and space weather. She actively researches the near-Earth space environment, space weather events, and their impacts on DoD and civil systems. Dr. Bishop has led the design, development, and testing of a CubeSat capable GPS Radio Occultation sensor to measure plasma density and scintillation inducing structures. She is the principal investigator of a NASA supported CubeSat mission to study the nighttime ionosphere as well as an instrument lead on the joint US-Brazil SPORT CubeSat mission. In addition to satellite instrumentation, Dr. Bishop has been a part of several sounding-rocket and International Space Station hosted experiments, and provided technical support to DoD, NASA, and NOAA satellite missions.

Dr. Seth Jonas, Principal for Space Strategy, Development, and Science, Lockheed Martin Corporation

Dr. Seth Jonas is the Principal for Space Strategy, Development, and Science at Lockheed Martin where he leads the strategic development of evolutionary and revolutionary platforms, sensors, software, and products to reduce risk from hazards and further scientific understanding. He has led a multitude of strategic studies and analyses to inform investments in science and technology to continue Lockheed Martin's global leadership in national security technologies and capabilities.

Prior to joining Lockheed Martin, Dr. Jonas served in multiple roles on the White House National Security Council, including Deputy Senior Director for Resilience and Response. He was a 2017 US-UK Fulbright Scholar, serving as a visiting researcher at Rutherford Appleton Laboratory and Deputy Head of Resilience (Acting) at the UK Government Office for Science. Dr. Jonas was a senior member of the research staff at the IDA Science and Technology Policy Institute, where he provided analysis and strategic guidance to the White House Office of

Science and Technology Policy and a variety other national security and science-focused executive branch agencies, including the development and implementation of the National Space Weather Strategy and Action Plan. Dr. Jonas has held fellowships at Los Alamos National Laboratory, Brookhaven National Laboratory, and with the JASON scientific advisory group for U.S. national security.

Dr. Delores Knipp, Research Professor in the Smead Aerospace Engineering Science Department, University CO Boulder

Prof Knipp studies space weather storms that deposit large amounts of energy in geospace and Earth's upper atmosphere. She investigates historical space weather events to understand the impacts these events have had on society and the US military. She is a retired USAF officer, former Editor-in-Chief of the Space Weather Journal and a Fellow of the American Meteorological Society.

Dr. Michael Morgan, Assistant Secretary of Commerce for Environmental Observation and Prediction, NOAA

Michael C. Morgan, Ph.D. is the assistant secretary of commerce for environmental observation and prediction. In this role, Dr. Morgan is responsible for providing agency-wide direction with regard to weather, water, climate, and ocean observations, including in situ instruments and satellites, and the process of converting observations to predictions for environmental threats. Dr. Morgan has more than 25 years of demonstrated scientific leadership. Prior to joining NOAA, he had most recently served as a professor and associate department chair in the Department of Atmospheric and Oceanic Sciences at the University of Wisconsin-Madison, where his research was focused on the analysis, diagnosis, prediction, and predictability of mid-latitude and tropical weather systems.

In addition to his roles at the University of Wisconsin-Madison, Dr. Morgan recently served on the World Meteorological Organization World Weather Research Programme's Scientific Steering Committee. In addition, he recently served as a member of the board of directors of the American Institute of Physics and as chair of their Public Policy Advisory Committee. He also recently completed two terms on the Board of Trustees of the University Corporation for Atmospheric Research (UCAR). Dr. Morgan has previously served as the division director for the Division of Atmospheric and Geospace Sciences at the National Science Foundation, and as an AMS/UCAR congressional science fellow, working in the office of U.S. Senator Benjamin Cardin (MD) as a senior legislative fellow on energy and environmental issues. Dr. Morgan is a fellow of the American Meteorological Society (AMS). He earned his S.B. in Mathematics and Ph.D. in Meteorology from the Massachusetts Institute of Technology.

Mr. Bill Murtagh, Program Coordinator, Space Weather Prediction Center, NOAA

Bill Murtagh currently serves as the Program Coordinator for the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC) in Boulder, Colorado. Bill is NOAA's space weather lead in coordinating preparedness and response efforts

with industry, emergency managers, and government officials around the world. Bill also serves as the National Weather Service lead in the National Science and Technology Council (NSTC), interagency committee to develop and implement actions in the 2019 National Space Weather Strategy and Action Plan (NSW-SAP). He is the co-chair of the interagency space-weather working group responsible for implementing the NSW-SAP plans and procedures for responding to and recovering from space weather events. Bill is NOAA's lead in the National Security Council interagency committee responsible for the development and implementation of Executive Order 13865 - Coordinating National Resilience to Electromagnetic Pulses.

In November 2016, he completed a 26-month assignment in the White House Office of Science and Technology Policy (OSTP) as the Assistant Director for Space Weather. In his position at OSTP he oversaw the development and implementation of the 2015 National Space Weather Strategy and Action Plan and coordinated efforts to develop Executive Order 13744 (2016) – "Coordinating Efforts to Prepare the Nation for Space Weather Events".

He regularly briefs the White House, Congress, and other government leadership on vulnerabilities of critical infrastructure to space weather storms. Bill is also a key contributor in U.S. government efforts to advance international cooperation in space weather-related activities. He is a regular guest speaker at universities, government agencies, and national and international conferences. He has provided numerous interviews to major media outlets and is featured in several documentaries on space weather.

Before joining NOAA, Bill was a weather forecaster in the United States Air Force. He coordinated and provided meteorological support for national security interests around the world. Bill transferred to the SWPC in 1997 as a space weather forecaster and liaison between NOAA and the U.S. Air Force. He joined NOAA in 2003 after retiring from the Air Force with 23 years of military service.

Craig Fugate, Former FEMA Administrator

Craig Fugate was appointed administrator of the Federal Emergency Management Agency by former President Barack Obama. He served as the FEMA administrator from May 2009 to January 2017. Fugate led FEMA through multiple record-breaking disaster years and oversaw the Federal Government's response to major events such as the Joplin and Moore Tornadoes, Hurricane Sandy, Hurricane Matthew and the 2016 Louisiana flooding. All total, Fugate led FEMA through more than 500 Presidentially declared major disasters and emergencies. Fugate set a clear and compelling vision, mission and priorities for FEMA and relentlessly drove the Agency to achieve better outcomes for survivors.
Previously, Fugate served as Florida's Emergency Management Director under former Gov. Jeb Bush (2001–2007) and former Gov. Charlie Crist (2007–2009). Fugate was widely praised for his management of the devastating effects of the 2004 and 2005 Florida hurricane seasons. Fugate currently provides senior-level advice and consultation in disaster management and resiliency policy through Craig Fugate Consulting LLC. He also serves as the chief emergency management officer at One Concern.

Mr. Matthew Payne, Deputy Assistant Administrator for Response, Office of Response and Recovery, FEMA

Mr. Matthew Payne currently serves as the Acting Deputy Assistant Administrator of the Response Directorate. In this role, he helps lead an organization that provides the core, coordinated Federal operational response capabilities needed to save and sustain lives, minimize suffering, and protect property in a timely and effective manner. Response program activities encompass the coordination of Federal emergency management response operations and planning.

Prior to this role, Mr. Payne served as the Deputy Associate Administrator for Policy and Program Analysis at FEMA. In this role, Matt supported the Associate Administrator in leading the Agency's strategic and resource planning, data analytics, policy, audit, and international affairs functions. Matt also served as the Director of the Policy Division within FEMA's Office of Policy and Program Analysis where he was responsible for the coordination, review, and approval of Agency, Departmental and national policies.

Prior to joining FEMA, Matt held numerous positions at the Office of the Assistant Secretary for Preparedness and Response (ASPR) at the U.S. Department of Health and Human Services (HHS). Over a fourteen-year career at HHS, he served as the Director of the Division of Policy and Strategic Planning, responsible for the development of the first National Health Security Strategy; Deputy Director for Operations overseeing the HHS Secretary's Operations Center during Hurricanes Katrina and Rita; deployed to New York City to support the National Disaster Medical System response to the attacks of September 11, 2001; provided medical screening for Congressional staff members exposed to anthrax in 2001; and served as a Program Manager for the Metropolitan Medical Response System program. Matt entered federal service in 1997 as a Presidential Management Intern in the HHS Office of Emergency Response.

Prior to his federal service, Matt worked as a paramedic, emergency call-taker, and emergency medical dispatcher in Syracuse, New York. Matt holds a Master in Public Administration from the Maxwell School of Citizenship and Public Affairs at Syracuse University, and a Bachelor of Arts in Biology from Syracuse University. He lives in Alexandria, VA, with his wife and their two daughters.

Mr. John Dudley, Managing Director, Flight Operations, American Airlines

Captain John Dudley serves American Airlines as Managing Director, Flight Operations, and FAR Part 119 Director of Operations.
John is now in his 38th year as an airline pilot.

John helped bring the Advanced Qualification flight training program to the Airbus fleet at US Airways in 2004, and during the America West-US Airways merger, John worked to harmonize flight deck procedures and training curricula.
His love of long-range flying led to involvement with the A350 program, including several years designing and developing the A350 flight deck and operating procedures at Airbus in Toulouse. John was the first airline pilot rated on the A350.

Returning from Toulouse in 2013, he served as the Training Manager and Fleet Captain of the A330/A350 programs for American.
John's ideas concerning non-normal methodology were used during the creation of new pilot procedures for handling non-normal flight scenarios at American.

John has an extensive background representing American Airlines in the worldwide aviation community. He currently serves as Chairman of the IATA Flight Operations Group, and is a member of the A4A Ops Council.

John received a BS degree in Aviation Management from Auburn University. He and his wife, Mintie, have four adult children.

Mr. Joe Woomer, Senior Vice President, Electric Transmission, Dominion Energy Inc.

Joseph A. "Joe" Woomer is senior vice president-Electric Transmission, Dominion Energy Virginia. He is responsible for over 6,700 miles of electric transmission lines and more than 800 substation assets providing service to the company's 2.7 million customers, which include transmission and substation planning, engineering, project development, construction, operations and maintenance, compliance, and the Electric Transmission System Operations Center. Woomer joined Dominion Energy in 1986 as an associate engineer in Northern Virginia and has held various engineering, operational, and leadership roles in Distribution Operations Centers, Reliability, and Electric Distribution Construction. In 2018, Woomer became vice president–Grid and Technical Solutions, Power Delivery Group, where he was responsible for the company's grid modernization efforts, technical and engineering aspects of Dominion Energy's electric distribution business unit, including design, grid planning, reliability, strategic undergrounding, advanced metering, energy efficiency, end-use technologies, renewable energy interconnections and electrification. In April 2022, he was named vice president–New Business and Customer Solutions at Dominion Energy Virginia, where he was responsible for implementation of new business lines to provide more comprehensive energy solutions to residential, commercial, and industrial customers, and leading the company's efforts to focus on areas of transportation electrification, solar and batteries, and drive product development. He assumed his current position in June 2023. He is a member of the EPRI Transmission Executive Committee, represents Dominion Energy as an Executive Champion at Virginia State University and Executive Steering committee 2023 LLS Light The Night Richmond. He is a former member of the Virginia 4H Foundation, Partnerships for Families and Gold Shovel Standard Boards. A native of Western Pennsylvania, Woomer earned his B.S. degree in electrical engineering from Penn State University in 1986 and graduated from the Tuck Executive Program at the University of Dartmouth in 2003.

Dr. Kathryn Draeger, Adjunct Assistant Professor, Statewide Director, Regional Development Partnerships, University of Minnesota

Kathryn Draeger is Statewide Director for the U of M Regional Sustainable Development Partnerships and adjunct professor of Agronomy and Plant Genetics. She oversees statewide programming in sustainable development, including clean energy and sustainable ag and food systems. Dr. Draeger is currently principle investigator on USDA-AFRI-NIFA grant to develop

innovative supply chains for locally produced food as well as other sustainable ag related efforts. She has been a Bush Leadership Fellowship and a MacArthur Scholar. She served as an Environmental Protection Commissioner in Iowa and was appointed to the Governor's Roundtable for Sustainable Development in Minnesota. Before joining the U she founded two successful corporations Sustainability International, Inc. and Environmental Ground, Inc. In 2007, Kathy and her family moved to rural Big Stone County MN to live and farm sustainably. Kathy holds a doctorate in water resources and master's in Soil Science from the University of Minnesota.

Mr. Mark Lauby, Senior Vice President and Chief Engineer, North American Electric Reliability Corporation (NERC)

Mark G. Lauby is senior vice president and chief engineer at NERC. Mr. Lauby joined NERC in January 2007 and has held a number of positions, including vice president and director of Standards and vice president and director of Reliability Assessments and Performance Analysis. In 2012, Mr. Lauby was elected to the North American Energy Standards Board and was appointed to the Department of Energy's Electric Advisory Committee by the Secretary of Energy in 2014. Mr. Lauby has served as chair and is a life member of the International Electricity Research Exchange and served as chair of a number of IEEE working groups. From 1999 to 2007, Mr. Lauby was an appointed member of the Board of Excellent Energy International Co., LTD, an energy service company based in Thailand. He has been recognized for his technical achievements in many technical associations, including the 1992 IEEE Walter Fee Young Engineer of the Year Award. He was named a Fellow by IEEE in November 2011 for "leadership in the development and application of techniques for bulk power system reliability." In 2014, Mr. Lauby was awarded the IEEE Power and Energy Society's Roy Billinton Power System Reliability Award. In 2020, the National Academy of Engineering (NAE) elected Mr. Lauby as a member, citing his development and application of techniques for electric grid reliability analysis. He is also a member of the IEEE Power & Energy Society (PES) Executive Advisory Committee, focused on providing strategic support to the PES Board of Directors.

Prior to joining NERC, Mr. Lauby worked for the Electric Power Research Institute (EPRI) for 20 years, holding a number of senior positions, including: director, Power Delivery and Markets; managing director, Asia, EPRI International; and manager, Power System Engineering in the Power System Planning and Operations Program. Mr. Lauby began his electric industry career in 1979 at the Mid-Continent Area Power Pool in Minneapolis, Minnesota. His responsibilities included transmission planning, power system reliability assessment, and probabilistic evaluation.

Mr. Lauby is the author of more than 100 technical papers on the subjects of power system reliability, expert systems, transmission system planning, and power system numerical analysis techniques. He earned his bachelor's and master's degrees in Electrical Engineering from the University of Minnesota. In addition, Mr. Lauby attended the London Business School Accelerated Development Program as well as the Executive Leadership Program at Harvard Business School.

Mr. Brent Blevins, Subcommittee Staff Director, US House Committee on Science, Space, and Technology

Since January 2023, Brent Blevins has served as the Staff Director for the Space and Aeronautics subcommittee of the House Committee on Science, Space, and Technology. Prior to his current role, he was Senior Policy Advisor for the subcommittee starting in 2019. Before that, he served as a Policy Advisor for U.S. Senate Majority Whip John Cornyn (R-TX) and as Senior Professional Staff for the House Committee on Agriculture and Natural Resources. A lifelong Hokie, Brent received a BA in History and Political Science (2003) and an MPA (2005) from Virginia Tech.

Mr. Clinton Wallace, Director, Space Weather Prediction Center, NOAA

Clinton Wallace is the director of NOAA's Space Weather Prediction Center (SWPC) in Boulder, Colorado. SWPC is the Nation's official civilian source of space weather alerts and warnings, and one of the National Weather Service's nine National Centers of Environmental Prediction.

Wallace has served as deputy director of NOAA's Aviation Weather Center in Kansas City, Missouri since 2010, where he fostered a world-class culture, expanded hiring, and oversaw major advances in decision support products and services to aviation customers.

Previously, Wallace was Chief of AWC's Aviation Support Branch from late 2003 to 2010, directing aviation research-to-operations and operations-to-research while championing the application of new innovations, collaborative science and applied research efforts. He also served as a Research & Development Meteorologist at AWC from 1999 to 2003, as an Agricultural Weather Analyst at the Climate Prediction Center from 1998 to 1999, and as a Research Associate with the Cooperative Institute for Mesoscale Meteorological Studies at the National Severe Storms Laboratory in Norman, OK from 1995 to 1998.

Wallace earned a Master's Degree in Meteorology from the University of Oklahoma in 1997, and graduated Cum Laude in 1994 from Northeastern State University in Tahlequah, Oklahoma with a Bachelor's Degree, double majoring in Engineering Physics and Mathematics.

A native of Oklahoma, Wallace and his wife, Brandy, look forward to enjoying Colorado's outdoor lifestyle.