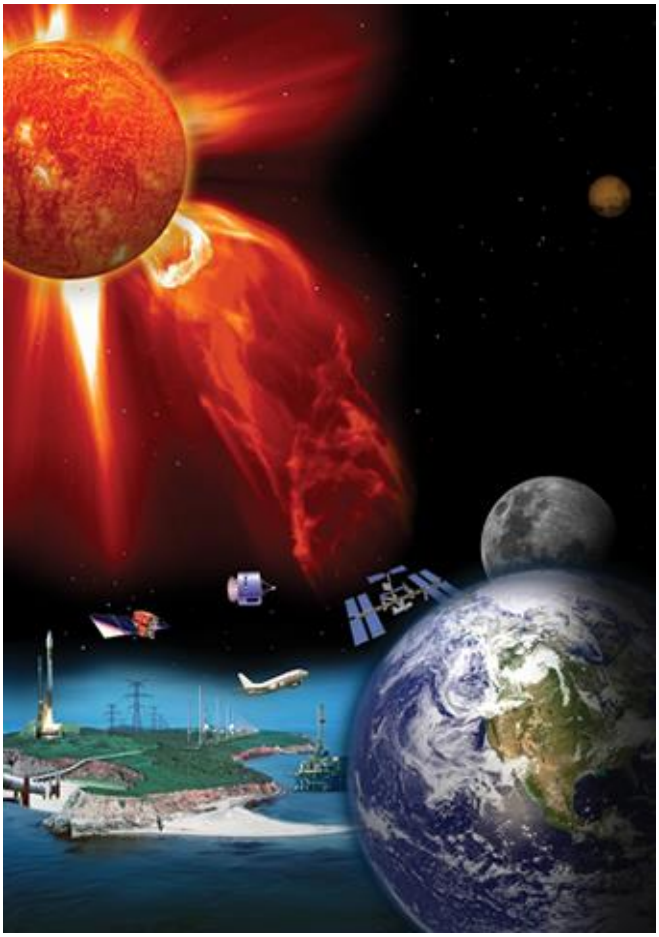
NATIONAL SPACE WEATHER PARTNERSHIP



2020 SPACE WEATHER ENTERPRISE FORUM

SUMMARY REPORT

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

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2020 SPACE WEATHER ENTERPRISE FORUM

SUMMARY REPORT

FEDERAL COORDINATOR FOR METEOROLOGICAL
SERVICES AND SUPPORTING RESEARCH
(OFCM)

Silver Spring Metro Center, Building 2 (SSMC 2)
1325 East West Highway, Suite 7130
Silver Spring, MD 20910
301.628.0112

November 2020
Washington, D.C.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

2020 SPACE WEATHER ENTERPRISE FORUM SUMMARY REPORT

This document provides a synopsis of the 2020 Space Weather Enterprise Forum (SWEF), an event sponsored by the National Space Weather Partnership (NSWP) and hosted by the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) by virtual webinar. This year's theme was "Implementing Space Weather Legislation, Strategy, and Plans to Protect the Nation."

Motivation

Last year's SWEF was conducted in the context of the recently-released National Space Weather Strategy and Action Plan (NSW-SAP). This second-generation plan reflected both the progress made since the National Space Weather Strategy was released in 2015 and the challenges that have yet to be fully addressed. The implementation process for the NSW-SAP has been agreed to and is now underway within the Federal agencies. We must foster continued engagement across the space weather enterprise to plan for, warn for, and respond to space weather events in the near term (the upcoming solar maximum) and in the long term.

The Forum

The Space Weather Enterprise Forum brings together the space weather community to share information and ideas among policymakers, senior government leaders, researchers, service-provider agencies, private-sector service providers, space weather information users, media, and legislators and staff from Capitol Hill to raise awareness of space weather and its effects on society. This year's event focused on continuity of critical space weather observations, transitioning research results into operations, and the application of space weather information to activities in space. Our ultimate goal is to advance the broader use of space weather information on a routine basis while improving the Nation's ability to prepare for, avoid, mitigate, respond to, and recover from potentially devastating impacts of space weather events.

Forum Objectives

- Discuss vulnerabilities of our technological infrastructure to space weather impacts
- Support actions to prepare for and respond to space weather impacts
- Highlight partnership opportunities between government, commercial, and academic stakeholders
- Emphasize the importance of new policy guidance pending space weather related legislation

Format

The 2020 SWEF was originally planned to revert to the half-day format introduced in 2018 after the full-day forum in 2019. This would establish the practice to alternate formats each year. However, the move to a virtual forum opened the opportunity to hold what was essentially a full-day forum over two abbreviated half day webinars. This allowed for broader participation of both panelists and participants because travel was not required and participants could, if dealing with time constraints, focus on those sessions of greatest interest.

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The 2020 SWEF was planned to coincide with the Space Weather as a Global Challenge event, which, unfortunately, had to be postponed until next year

A panel format was used, which included presentations by the expert panelists followed by questions from a diverse group of attendees. The agenda was developed by the interagency SWEF Organizing Committee. Forum presentations can be found at: https://www.ofcm.gov/meetings/swef/swefmeeting.htm.

Forum Sponsors

This Forum was sponsored by the Secure World Foundation, the American Commercial Space Weather Association (ACSWA), and the National Space Weather Partnership (NWSP), which organized it through OFCM.

Session 1: Opening and Welcome

Mr. Michael Bonadonna, the Director of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) and Executive Secretary for Space Weather Operations, Research, and Mitigation (SWORM) Interagency Working Group of the National Science and Technology Council (NSTC), opened the Forum. He set the stage for the next two days' events by reviewing the history of the National Space Weather Program since its inception in 1995 after which he discussed the make-up and work of two key space weather organizations—the NSWP and the SWORM. He then reviewed the history of the SWEF and presented the objectives and agenda for this year's forum. Mr. Bonadonna wrapped up his opening remarks with a few comments about the background and intent of the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act. Those comments led into the introduction of the Honorable Ed Perlmutter, United States Representative.

Congressman Ed Perlmutter represents the 7th Congressional District of Colorado. Starting in 1994, Congressman Perlmutter served two terms as a Colorado State Senator, during which he built a reputation as a bipartisan bridge-builder and a champion of renewable energy and smart growth policies. He was first elected to represent the 7th Congressional District 2006 and is currently serving in his seventh term. Representative Perlmutter serves on the Financial Services, Rules, and Science, Space and Technology committees. Over the past four years, he has championed the development of the PROSWIFT Act, which became Public Law No: 116-181 on Oct 21, 2020.

In his recorded remarks, Representative Perlmutter recalled that he last addressed the SWEF in 2018. At that time he had been working for several years on space weather legislation. Since then he and his colleagues, with the leadership of Senators Gary Peters and Cory Gardener and Representative Mo Brooks, have succeeded in getting the PROSWIFT act through Congress and signed by the President. He thanked all those who supported the effort along the way. He pointed out that the Act delineates the roles of the agencies and adds important voices to the organization of the enterprise—academia and the commercial sector will join with operational space weather representatives. The bill also establishes an advisory group and a roundtable, and includes mandates to help break down communication barriers between research and operations. He invited SWEF participants to get back with him and let him know how the PROSWIFT is working to support the space weather enterprise and signed off with the hope that this year's SWEF will be successful.

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Mr. Bonadonna thanked the congressman and his staff for making his address possible, and invited participants to submit questions, which would be passed to the congressional staff.

Session 2: Implementing an Integrated Strategy – Sustaining and advancing critical space weather capabilities

Moderator: **Dr. Aaron Miles**, Principal Assistant Director, National Security and International Affairs, The White House Office of Science and Technology Policy (OSTP) and OSTP Co-Chair of the Space Weather Security and Hazards Subcommittee and SWORM IWG

Dr. Miles expressed his gratitude for the opportunity to participate in the SWEF and provided a brief overview of the NSW-SAP. The plan was developed by a collaborative process involving a broad spectrum of federal participants in the SWORM WG and released in March 2019. It built directly on the work performed under the previous Plan, released in 2015. The updated plan included two areas of increased emphasis—the potential national security implications of space weather and the recognition of the impacts of less dramatic, low intensity events that occur more frequently and can, over time, degrade or shorten the life of infrastructure systems. The plan articulates three over-arching objectives:

1. Enhance the protection of national security, homeland security, and commercial assets and operations against the effects of space weather;

2. Develop and disseminate accurate and timely space weather characterizations and forecasts; and

3. Establish plans and procedures for responding to and recovering from space weather events.

Dr. Miles reviewed some of the key high-level actions in the plan that support each of these objectives. Since the release of the plan, agencies have been working toward its implementation, and the panelists in this session are leading that implementation. With that background, he introduced the panelists.

Panelists:

- **Dr. Louis Uccellini**, National Oceanic and Atmospheric Administration (NOAA) Assistant Administrator for Weather Services and Director, National Weather Service

  Dr. Uccellini reviewed the three objectives of the NSW-SAP that Dr. Miles had just presented, noting that the National Weather Service (NWS) focuses on the second—developing and disseminating space weather forecasts. However, the effort is not just about improved forecasts and warnings, it drives toward helping decision makers react to and recover from space weather events—a resilience-based outcome. This comes from understanding and responding to the needs of the stakeholders. Dr. Uccellini pointed out that the Space Weather Prediction Center (SWPC), since its inception in 2005, has evolved toward supporting space weather similarly to the way much of NWS supports terrestrial weather based on user needs. Real-time, continuous, operationally-dedicated observational data support models as well as forecasts, watches, and warnings suitable for objective decision making. The center is working to accelerate the development of forecasting models by engaging the other federal agencies, academia, and industry. He highlighted two observing systems belonging to other agencies that the

center is leveraging to support their operations. NOAA is now supported by the six Global Oscillation Network Group (GONG) observatories, and is working with the National Science Foundation's National Solar Observatory to operationalize the GONG data. Similarly, the USGS ground-based magnetometers provide critical input to SWPC warnings. Dr. Uccellini highlighted efforts to sustain baseline observing capabilities, with four sensors on the current GOES series (with a fifth—a coronagraph—planned for GOES U in 2024), plans to rideshare to L1 with a NASA mission in 2024, and radio occultation measurements from COSMIC-2A's six satellites. He then talked about the models that the observations support. He discussed the four models that are running at SWPC to characterize the atmosphere from the surface of the sun to the surface of the earth, including the new Whole Atmosphere Model, which is running experimentally. Regarding R2O2R, Dr. Uccellini emphasized the partnerships NWS has with other agencies, the importance of the Community Coordinated Modeling Center at Goddard Space Flight Center, and the work underway to establish the Space Weather Testbed at SWPC. He went on to illustrate the importance of using these partnerships to improve services with a graph that showed a steady increase in subscribers to SWPC throughout the recent solar minimum. He wrapped up his talk by citing the PROSWIFT Act and its provisions that engage academia and industry, emphasizing that private sector is part of the value chain from observations to forecasts and is fully involved in improving the science and technology of space weather.

- **Bob Kolasky**, Director, Cybersecurity and Infrastructure Security Agency, National Risk Management Center, DHS

  Mr. Kolasky mentioned that he is not a space weather expert, but rather works to address strategic risks to the nation's infrastructure. Space weather, in particular geomagnetic disturbances, presents one of those risks that demands national coordinated attention. He runs the National Risk Management Center, a planning, analysis, and collaboration organization within the Cybersecurity and Infrastructure Security Agency. The center works with owners, operators, and agencies responsible for 16 infrastructure sectors, including the energy sector. They apply a structured approach to regularly engage on risk areas, coordinating to provide information about risks and advice on how to address threats in order to mitigate vulnerabilities and impacts. Mr. Kolasky cited election security supporting state and local election officials as a very visible example of the type of work they do. Over four years they have helped to elevate election security to a significantly higher level. This includes the cybersecurity infrastructure. That's the type of work DHS is bringing to table to address the threat brought on by space weather. They take a risk management approach, getting information it to the hands those deciding on the appropriate level of investment to manage the risk. They also work the technical side of the issue, helping to determine what needs to be done to mitigate risk in the context of balancing cost against risk. It's important to get actionable information into the hands of those in industry who can assess vulnerability and make decisions to reduce risk. DHS has also done work in other sectors affected by space weather, including communications, navigation, financial data, etc. Work done in these sectors falls within 55 Nation Critical Functions, which provide a framework for prioritizing on a national level were the greatest return on investment can be achieved. When it comes to geomagnetic storms, there is

sometimes a lack of expertise among operators, so it's important to provide information to help them understand the risk, take it seriously, take action.

- **Dr. Chris Cannizzaro**, Director of Critical Infrastructure, National Security Council

  Dr. Cannizzaro recalled that he last spoke at a SWEF in 2018 in a State Department role. The SWEF that year followed the third Space Weather as a Global Challenge event, which resulted in broader international participation at the SWEF and more opportunity for speakers to address an international audience. The State Department was planning to host the fifth Space Weather as a Global Challenge this year, but due to Covid-19 that event has been postponed until next year. Dr. Cannizzaro joined the National Security Council in September where he continues to work on space weather, but from a much broader perspective. The National Security Strategy (2017) serves as the baseline policy to communicate the executive branch's national security vision for protecting the American people, preserving the way of life, promoting our prosperity, preserving peace through strength, and advancing American influence in the world. It highlights the importance of the space domain and calls for maintaining American leadership in space. The National Space Council was reestablished in 2017 and is well positioned to look at space from a whole of government perspective across the civil, commercial, and nation security domains. The National Security Strategy (NSS) calls for promoting American resilience, which involves improving risk management. The 2017 NSS, for the first time in history, identified electro-magnetic pulses (EMPs) as a risk to the nation. EMPs include geomagnetic disturbances, which are a natural form of EMP. Working toward realizing the NSS vision, the administration released an executive order (EO) in March 2019 coordinating national resilience to EMPs. Meanwhile, the NSW-SAP addressed planning for, warning for, and responding to natural EMPs. Implementation of the EO is on-going, but several related successes can be highlighted. In June of this year the National Science and Technology Council published a federally-coordinated report on improving resilience to EMPs. It identified twelve research needs across the critical infrastructure sectors. In response to the EO's call for completing the magentotelluric survey over the contiguous United States, the USGS has established plans to complete the survey by 2023. Further, in May 2019 the DHS released the Federal Operating Concept for Impending Space Weather Events, which provides guidance for the federal departments and agencies to use in the development of their operation plans to prepare for, protect against, and mitigate the effects of impending space weather events. Preparing for space weather is an important aspect of building resilience. We've made excellent progress toward this end in the last decade, but there is much yet to be done.

Q & A:

- *How can the federal government further prepare for space weather events? What are your top priorities, and how can the commercial sector help?* Dr. Uccellini: we have to work not just across the government, but internationally and at all levels in the U.S., including state and local. Global cooperation is important--we helped the UK Met Office stand up their space weather capabilities a decade ago, and we benefit from that by collaborating with them every day. We're also working with

Australia. We make our information available across the enterprise, and we believe it's in our best interest to do so.

- *How does preparation for space weather events compare with preparation for other natural and human threats?* Mr. Kolasky: We think in terms of functions that are affected by space weather, and ask whether users have plans in place to continue performing those functions in the face of things that you depend on being degraded or unavailable. While space weather may have unique impacts, the process of preparing for those events is similar in terms of applying science and engineering effectively to get to where we need to be.
- *How do we engage with international partners, and where are the best opportunities for collaboration?* Dr. Cannizzaro: As identified in the NSW-SAP, we live in a world that's dependent upon interconnected infrastructure, vulnerable to impacts beyond one country. We approach this with four high-level objectives for coordination with the international community. First, build support and policies for acknowledging the treat of space weather impacts. Secondly, increase engagement on observational infrastructure, data sharing, modeling, etc. Thirdly, strengthen international coordination and cooperation on space weather products and services. Finally, promote a cooperative international approach to preparedness.
- *How can NOAA partnership with Canada on the tundra arctic observing mission with an auroral imager benefit space weather services?* Dr. Uccellini: the aurora data are important at least as a verification tool, but all data are important if we have immediate access to it and can make it available to others.
- *Lead times for space weather observing systems tend to be very long. How can we accelerate the process of fielding systems to be more responsive to changing needs and technologies?* Dr. Uccellini: There tends to a sense of inertial in operations, even among users, but we'd like to move faster. We usually move forward by adding on to capabilities. We need good reasons to invest in disrupter capabilities. We're trying to build a better O2R infrastructure to move more quickly, but even that takes time.
- *Have northern European countries' power grid managers coordinated on space weather impacts to the extent that their U.S. counterparts have?* Dr. Cannizzaro: We've had discussions with those countries about that topic. However, it can be difficult to determine who to engage for a regional or European approach seeing as though the European Space Agency, the European Commission, and NATO have varying missions and memberships.

Session 3: Understanding and Preparing for Extreme Space Weather Events.

Moderator: **Dr. Mangala Sharma**, Program Director, Space Weather Division of Atmospheric and Geospace Sciences (NSF)

Dr. Sharma introduced the topic by citing extreme space weather events going back to the Carrington event in 1859, the Quebec blackout in 1989, and a near miss in 2012. This session is about understanding and preparing for such events, which could cause widespread electrical power outages, harm astronauts' health, disrupt radio communications, interfere with navigation systems, and cause cascading effects on

banking, air travel, and numerous other technological capabilities. She introduced the panel members for this session by detailing what they do to help the nation understand and prepare for extreme events.

- **Dr. Geoff Reeves**, Senior Scientist, Space Sciences and Applications Group, Los Alamos National Laboratory (LANL)

  Dr. Reeves explained that not just satellite systems are affected by space weather, but satellite instruments and the data they produce can be affected. That's why LANL, which is mostly concerned with nuclear security, is concerned about space weather. Dr. Reeves led the development of the Space Weather Phase 1 Benchmarks, which were called out as a goal of the 2015 National Space Weather Action Plan. The SWORM subcommittee completed the developed the benchmarks in 2018 and a panel subsequently reviewed that product and provided recommendations for improvement (called the Next Steps study). The benchmarks are specifications of extreme space weather conditions rather than metrics for model/prediction performance. They specify particular extreme conditions that can affect infrastructure, but do not evaluate or classify the effects. The benchmarks increase awareness, provide input for vulnerability and risk assessments, support development of engineering standards, establish thresholds for action, and set research goals. The benchmarks address five space weather phenomenologies: geoelectric fields, ionizing radiation, ionospheric disturbances, solar radio bursts, and atmospheric expansion. Effects associated with each of these phenomenologies were provided in the report, which included a description of the phenomenon, methodology for determining the benchmarks, and the 1-in-100 year and theoretical maximum events. He showed how data was extrapolated to a 1-in-100 year event when 100 years of data were not available. Dr. Reeves went on to describe the guidelines for the Next Steps review of the benchmarks. The focus should again be on physical quantities, not effects on systems, and have utility for both current and future systems. While addressing security of US infrastructure, they should recognize the need for broader collaboration. He concluded his talk by reviewing the recommendations that came out of the next steps study: in addition to the 1-in-100 year and worst case events, a one-in-N year specification would be helpful; a data collection plan for current and future data should be included; and including duration of events along with intensity would be useful. They also provided a series of broader research recommendations.

- **Ms. Kenyetta Blunt**, Deputy Director, Planning and Exercise Division, Federal Emergency Management Agency (FEMA)

  Ms. Blunt began by noting that FEMA had not traditionally prepared for space weather events. The agency started addressing those events in 2013, and got more involved after EO 13744 was issued in October 2016. That order called for the creation of a Federal Operating Concept for Impending Space Weather Events, which would coordinate federal assets in response to the notification of an event. The Concept was published in May 2019. Although it is a federal document, it was released publicly so that emergency managers, private industry, and others would know how the federal government planned to respond. It outlines the preparatory actions the departments and agencies are to take, including developing their own operational plans. In particular, it requires a risk analysis to evaluate vulnerabilities and potential consequences, identifies

the agencies responsible for notification of elevated threat or actual event, and mandates protective actions. It also encourages agencies to develop backup systems as needed and requires FEMA to initiate coordination between governmental (federal, state, and local) and non-governmental organizations. In response, FEMA developed the Power Outage Incident Annex (POIA), which provides guidance for federal responders on how to provide support in the event a massive power outage. The POIA is not an electricity restoration plan, but rather it outlines the types of federal support available to critical infrastructure stakeholders and the responsibilities of industry stakeholders. While the POIA was developed in response to potential space weather events, it is cause-agnostic, and as such it was applied successfully in response to power outages across Puerto Rica caused by Hurricane Maria. Ms. Blunt wrapped up her talk by discussing FEMA actions related to space weather impacts other than power outages. These are being addressed under the third objective of the NSW-SAP. This work includes helping agencies develop response plans for all types of space weather effects, developing relevant training material for scientific, national security, and emergency management professionals, and developing guidance for operating communications systems during and after a space weather event.

- **Mr. Lindley Johnson**, Planetary Defense Officer and Program Executive, Planetary Defense Coordination Office (NASA)

  Mr. Johnson started by explaining that his talk was intended to provide insights into detecting and responding to a threat from space unrelated to space weather that might be useful to the space weather community. He cited as an example the discovery of a near earth asteroid in 2018 that was eventually determined to be a threat to impact the earth. In the 8 hours between discovery and impact, it was tracked by a number of telescopes and determined to be small enough to burn up before striking the earth. The length of the initial impact corridor was reduced from about 180° longitude to a short swath across southern Africa (a bolide was detected over Botswana). A number of US government sensors report events involving bodies over a meter in size, including about 850 events over the last 12 years. The most significant of these occurred over Chelyabinsk, Russia in 2013, when a 20 meter object caused about $30 million damage and injured over 1600 people. The Planetary Defense Coordination office was established in 2016 to detect this type of threat, appraise the range of potential effects, and develop strategies to mitigate those effects. The office tracks near earth objects with orbits that bring them within 4.7 million miles of the Earth's orbit that could do regional damage upon impact (objects at least 140 meters in diameter). They respond to the National Near-Earth Object Preparedness Strategy and Action Plan (June 1018), which provides five goals for the interagency to enhance our capabilities over the next ten years. Those goals are to enhance capabilities to detect, characterize, and track objects; improve modeling and predictions; develop technologies for deflection/disruption; increase international cooperation; and establish emergency procedures. Mr. Johnson pointed out that there were 77 detected events last year when asteroids came within one lunar distance of the earth. Most were small, but two were larger than 100 meters. After 20 years of searching, about 40% of the estimated 25,000 objects 140 meters in diameter or larger that threaten the earth have been found. The current progress suggests that it will take at least 30 more years to complete the survey. The mitigation techniques being considered (kinetic impactor, gravity tractor, and nuclear explosive

device) would slightly change the orbit of the threat body. None of these techniques have been proven; however, a kinetic impactor test has been developed involving a controlled impact experiment on a binary target (Dimorphos). It is due for launch next summer and impact in fall of 2022.

Q & A:

- *In the benchmarks, was duration considered, and how critical is that factor?* Dr. Reeves: duration was not included in the Phase 1 Benchmarks; but it is considered to be important, and the Next Step report recommended that duration should be included in the next phase.
- *A spacecraft operator pointed out that not all impacts on spacecraft are from extreme events. How can the benchmarks include information on events that are not extreme?* Dr. Reeves: the recommendation from the Next Steps panel to include 1-in-N year data was intended to address that problem in the phase 2 benchmarks.
- *How important is it to collect, share, and use data?* Dr. Reeves: We're relatively new at this, and data can be hard to come by; so, of course, what we do have is important. It's also important to develop new analysis techniques. Further, we need to work on modeling for extremes—those events that seldom happen and perhaps haven't been observed, but are possible. Mr. Johnson: we can't do their job without data, and we rely on data from around the world. Ms. Blunt: the data define what they have to plan for in terms of scale and intensity of events.
- *What is FEMA doing to inform the general public about space weather hazards?* Ms. Blunt: FEMA has released the Federal Operating Concept on FEMA.gov. Further, although the training materials they're developing are targeted at federal, state, and local responders, they will be made available to the general public.
- *Millersville University offers a graduate certificate in space weather and environment. Many of the elements of FEMA's programs align with their program. Can they work with FEMA to optimize their efforts and avoid duplication*? Ms: Blunt: Yes. FEMA is interested in partnerships like this.
- *What is the operational role of the UN in Near Earth Object observations*? Dr. Reeves: The UN doesn't have an operational role in this effort. It helps facilitate international cooperation among space-capable nations. The International Asteroid Warning Network in a "coalition of the willing," not a UN body.
- *How important is the role of the private sector in investigating the impact in the space weather events or collecting the date.* Mr. Johnson: Almost all observations are not from NASA. They come from universities and space institutes in the US, facilities in other nations, and some very talented amateurs. Dr. Reeves: One of the challenges of getting data from the private sector is that collection had to be real-time. That is sometimes difficult for the private sector to achieve.
- *Have there been exercises in response to the Federal Response Plan?* Ms Blunt: There have been exercises at the senior level. FEMA is looking into ways to incorporate a space weather element into national-level exercises.

Session 4: Improving Research to Operations; Operations to Research Capabilities

Moderator: **Dr. Michael Wiltberger**, Geospace Section Head, National Science Foundation

Dr. Wiltberger set the stage by highlighting several successful efforts of moving space weather models from research to operations. NOAA, NASA, and NSF have established an memorandum of understanding to cooperate on bring research models into operations, and a sub-objective of the NSW-SAP calls for identifying mechanisms for sustaining and transitioning models and observational capabilities from research to operations.

- **Lt Col Omar Nava**, Chief of Space Weather Integration, Director of Weather, Headquarters United States Air Force

  Lt Col Omar started by pointing out that from a DoD perspective, Research to Operations; Operations to Research (R2O2R) is actually O2R2O; that is, it starts and ends with operations. That led to a description of the O2R2O process. The Space Weather Analysis and Forecasting System (SWAFS) drives the process. Lt Col Nava highlighted the levels of research and development and the main players in the Air Force and DoD. He then provided a detailed look at the O2R2O process. It starts with the identification of capability shortfalls by operators. From those shortfalls come operational requirements, which are fed into the research community. The research community (labs, academia, commercial entities) develops new capabilities, which are transferred to into the operational centers. The transfer involves prototyping and a utility assessment. The time involved in the transfer depends on the technology readiness level and, if the technology is a model, the operational availability of data. While the process is circular, any particular requirement and the development of the capability to meet that requirement have a clear beginning and end. Lt Col Nava then cited the Oval Variation, Assessment, Tracking, Intensity, and Online Nowcasting (OVATION)-Prime 2013 model as an example. This model replaced the Hardy Auroral Model, which had data latency problems. A key part of the new model was hardening to insure that it could handle real-time data (which can be missing or erroneous) and run efficiently in a shared operational environment. Model developers and the integration team worked together during the development process to include integration issues into the development process, and research scientists were included in the transition process. After deployment to operations, end users identified visualization problems that were addressed by developers. Lt Col Nava wrapped up his briefing with five recommendations for O2R2O: keep stakeholders involved throughout the process; integrate software engineers, developers, and scientists into the R2O process; validate models using operational data; not all models and data are appropriate for transition—identify those that are; implement a developmental sandbox.

- **Dr. Michele Cash**, Research Section Lead, Space Weather Prediction Center (NOAA)

  Dr. Cash focused on advancing R2O2R at the SWPC. She started by highlighting the policy initiatives over the last 6 years that have called for the development of a mechanism to transfer space weather research to operations. This effort started with the lead-up to the 2015 National Space Weather Strategy and has continued through the signing of the PROSWIFT Act last month. She pointed out that while the components for R2O2R existed across the enterprise, the system was *ad hoc*. There was no formal

framework to incorporate the federal agencies, academia, the private sector, and international partners into an organized team. Such a framework would encompass an R2O processes to evaluate, prototype, and transition new capabilities and O2R processes to improve existing operational capabilities, inform future capabilities, and establish research priorities. Key elements of the framework would include testbeds and proving grounds, joint interagency governance, and processes to engage academia and the private sector. These elements would support a shared transition process that defines roles, incorporates and leverages best practices, and engages outside users. She briefly discussed NOAA's existing testbeds and proving grounds and illustrated how space weather research will be funneled from the various sources of new technology, through testbeds and proving grounds, to operations at the SWPC and the Air Force's 557th Weather Wing. Dr. Cash then discussed the existing space weather models being used to analyze and/or forecast in the various domains of the sun-earth environment and the new models under development in each of those domains. These include some recent R2O successes: WSA-Enlil heliospheric model v2.0 in May 2019, 3-D conductivity joint NOAA-USGS Geoelectric-field model in September of this year, and the Geospace model v2.0 to be implemented next month. She went on to describe the work underway at SWPC to transition the Whole Atmosphere Model and associated Ionosphere Plasmasphere Electrodynamics model to operations. These models will allow the SWPC to support a growing customer base involved in low earth orbit activities such as space traffic management, orbit prediction, conjunction prediction, collision avoidance, and re-entry analysis. Dr. Cash concluded her briefing by highlighting the aims of ongoing and future R2O2R development activities and some of the work underway to achieve those aims. That work includes developing a plan that defines how to transition capabilities from a wide range of research efforts into SWPC operations, and establishing a Space Weather Proving Ground Executive Board and Science Steering Committee.

- **Dr. Nicky Fox**, Director, Heliophysics Division (HQ NASA)

  Dr. Fox opened her presentation by reviewing the NASA Space Weather Strategy, including its vision, mission, and goals. The NASA Heliophysics Division is establishing a Space Weather Council (SWC) under the Heliophysics Advisory Committee and developing a space weather implementation plan. That plan is being developed by the Space Weather Science Applications (SWxSA) Team, a group that leverages capability across NASA, including from the field centers. NASA recently released the Space Weather Instruments and Missions for Science (SWIMS) Request for Information (RFI) to assess community interest, concepts, and costs for single instruments, instrument suites, and complete missions. Dr. Fox provided a summary of the sources, content, targeted science areas, and other aspects of the 54 responses to the RFI before moving on to discuss the impact of the PROSWIFT Act on NASA's work. She emphasized that the Act allows NASA to focus on what they do best, which is pushing the limits of our understanding of the sun-earth system. After mentioning two international collaborations (discussions with ESA about adding science instruments to the L5 mission and with the Canadian Space Agency on participating in the Arctic Observing Mission), Dr. Fox presented more detailed information on the NASA Space Weather Strategy. She discussed each goal (observe, analyze, predict, transition, support, and partner) and the objectives supporting each goal. She wrapped up her talk

by enumerating existing and new contracts supporting space weather initiatives. These include a series of R2O efforts for which NOAA helped establish the focus of the work, Small Business Innovative Research grants, and a joint effort with NSF supporting a number of contracts for quantifying uncertainties associated with space weather.

Q & A:

- *What are connections between NOAA's space weather "proving ground" that Dr. Cash discussed and "sand box" that Lt Col Nava proposed?* Dr. Cash: in the end there are two centers that apply the results of R2O (SWPC and 557WW), but there is a lot of room for collaboration. NOAA is looking forward to working with DoD, but there are a lot of details to be fleshed out. Lt Col Nava: the DoD is looking forward to working with NOAA and NASA in the space weather test bed.
- *Will researchers have the opportunity to work in the operational environment in the test beds?* Dr. Cash: NOAA is still working how that will happen. One approach would be to put models in a cloud where both researchers and operators could work on them together as they move through the process. Lt Col Nava: We see this as an opportunity to groom experts in O2R2O over time as part of the process. Dr. Fox: one of the SBIR activities mentioned earlier is intended to enhance cloud operations at the CCMC, which would contribute to integrating R2O work.
- *Could you expound on the SWIM program?* Dr. Fox: SWIM is intended to determine what high technical readiness level instruments could be available to add on to other missions on relatively short notice if the opportunity presents itself. The instruments on the lunar gateway are an example of this—they were pulled together in about two years. SWIM will also identify opportunities for dedicated space weather science missions or more deliberate inclusion in larger missions. Lt Col Nava: the DoD's interest would be how these instruments can support operations.
- *How will the agencies involved in R2O2R determine priorities and communicate them to those not involved in the process?* Dr. Cash: Priorities would be established by the Space Weather Proving Ground Executive Board and Science Steering Committee mentioned earlier, and other means. For example, announcement of O2R grants will provide an indication of future R2O efforts. Dr. Fox: NASA will also provide input into priorities through the National Academy's gap analysis activities and use the Space Weather Council to get community input. Lt Col Nava: priorities would be based as they normally are in the DoD on user needs and available technology.
- *Will the operators be involved in the proving ground process?* Dr. Cash: absolutely. The test bed is a physical location where the operators will come together with researches and the transition team to make sure that the result will support them. Lt Col Nada: the operator drives the process and must be involved in the transition to made sure that the product meets operational requirements.

Session 5: Day Summary and Wrap-Up

Mike Bonadonna reviewed the highlights of the day. Congressman Ed Perlmutter kicked off the 2020 SWEF with a discussion of the PROSWIFT Act and how it will help our community as we move forward. We moved on to Aaron Miles and his SWORM IWG co-

chairs and NSC representative discussing implementation of the NSW-SAP. They emphasized that putting the need first—dealing with space weather impacts—has been the key to success since the SWORM went to work in 2015. After lunch Dr. Sharma brought a group of experts together to discuss defining the extremes in space weather and plans for dealing with them. That session included a presentation on dealing with the threat of near earth objects, an initiative with many parallels to space weather and from which the space weather enterprise can learn. We closed the day with Dr. Wiltberger's panel on R2O2R, one of the most important challenges facing the space weather community. Mr. Bonadonna informed participants that a summary of the SWEF will be made available within a few weeks on the OFCM web site along with the final agenda and copies of the presentations. He invited participants to join again tomorrow morning when Congressman Mo Brooks will keynote the second day of the SWEF. Finally, he thanked Representative Perlmutter; today's speakers, moderators, and panelists; SWEF partners—the Secure World Foundation, the American Commercial Space Weather Association, and the National Space Weather Partnership; and the SWEF organizing committee and OFCM staff.

Session 6: Day 2 Opening Remarks

Mr. Michael Bonadonna opened the second day of the 2020 SWEF with remarks similar to those he made on the first day. He reviewed the history of the National Space Weather Program since its inception in 1995 after which he discussed the make-up and work of two key space weather organizations—the NSWP and the SWORM. He then reviewed the history of the SWEF and presented the objectives and agenda for this year's forum. Mr. Bonadonna wrapped up his opening remarks with a few comments about the background and intent of the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act. Those comments led into the introduction of the Honorable Mo Brooks, United States Representative.

Congressman Mo Brooks represents the 5th Congressional District of Georgia. He was first elected to public office as a member of the Alabama House of Representatives in 1982 and has since been elected to public office 13 times as a state legislator, County Commissioner, and as a U.S. Congressman five times. Congressman Brooks serves on two influential House committees: Armed Services Committee and Science, Space, and Technology Committee. He also serves on three important House subcommittees: the Strategic Forces and Readiness Subcommittee under the Armed Services Committee and the Space Subcommittee on Science, Space, and Technology Committee. Over the past four years, Congressman Brooks has championed the development of the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act enacted as Public Law No: 116-181 on October 21, 2020.

Congressman Brooks expressed his appreciation for the opportunity to share his views with this year's SWEF participants. He began by describing the area he represents as the "birthplace of America's space program" where Wernher Von Braun located his team of rocket scientists after World War II. The 5th Congressional District hosts the Army's Redstone Arsenal and NASA's Marshall Space Flight Center, lending the name "Rocket City" to Huntsville—where the Chamber of Commerce proclaims that the sky is <u>not</u> the limit. He reminded the participants that about a month ago President Trump signed Senate Bill 881, the PROSWIFT Act. Representative Brooks was the lead Republican on the House companion bill, which was introduced by Congressman Perlmutter, who we heard

from yesterday. The Act is the most far-reaching federal space weather legislation ever enacted, ushering in a new era of space weather research. It declares that it will be US policy to prepare for and protect from the social and economic impact of space weather events through a number of measures including advancing space weather models and promoting research opportunities. It restructures the federal policy coordination process to optimize input from across the space weather enterprise. With the passage of this act, Alabama's 5th district will continue to play an important role understanding and mitigating space weather impacts. Marshall Space Flight Center has been at the forefront of space weather research, and the University of Alabama at Huntsville recently received research grants from NSF and NASA to develop data-driven models of the solar atmosphere and inner heliosphere. We now need a whole-of-government approach to understand the consequences of severe space weather events, and the PROSWIFT Act provides the guidance to lead us into the next frontier. Representative Brooks pointed out that when the president signed the PROSWIFT Act into law, he issued an accompanying statement saying that more work needs to be done to understand and deal with space weather effects on our national security assets. That issue will be a high priority going into the 117th Congress. He emphasized the importance of addressing space weather impacts on defense assets by citing a 1967 event during which a solar flare resulted in indications that we were being attacked. Fortunately, space weather forecasters intervened to flag down the on-going U.S. response, and the potential for a nuclear war was avoided. He also pointed out the importance of understanding and being able to forecast space weather effects on our efforts to return to the moon. Before hustling off to a floor vote, Congressman Brooks invited the SWEF participants, representing the space weather enterprise, to let him know what else besides the provisions of the PROSWIFT Act Congress should do to help insure the success of our space weather program.

Mr. Bonadonna thanked the congressman for his efforts in getting the PROSWIFT Act through congress and for speaking with us.

Session 7: Role of the Space Weather Advisory Group

Moderator: **Dr. Devrie Intriligator**, Director, Space Plasma Laboratory, Carmel Research Center, Inc. and member, American Commercial Space Weather Association (ACSWA) Executive Committee

Dr. Intriligator introduced the topic by pointing out that the provisions in the PROSWIFT Act identify roles for the private sector and academia in advancing space weather capabilities. These provisions include entering into an arrangement with National Academies to establish a Space Weather Government-Academic-Commercial Roundtable, establishing a pilot program with the commercial space weather sector for the provision of space weather data, and establishing a Space Weather Advisory Group (SWAG). The SWAG is to be composed of five members each from the academic sector, the commercial sector, and the end users. The SWAG is charged with informing the interests and work of the SWORM. Dr. Intriligator introduced the panel members with the details of their backgrounds, then invited them to speak.

- **Dr. Jennifer Gannon**, Strategic Director, Computational Physics, Inc. and member, ACSWA Executive Committee

Dr. Gannon began her briefing by explaining that ACSWA is a consortium of space weather businesses whose goal is to be a voice for the commercial sector and an advocate for space weather enterprise. She highlighted the importance of innovation across the enterprise, and stated that the commercial sector supports three attributes of cost-effective innovation: bootstrapping, diverse contributions, and feedback. Bootstrapping is important because technological growth typically follows an s-shaped curve—starting slowly, gaining momentum, then tapering off. Bootstrapping is building a new technology off an existing one, essentially a series of s-shaped curves where new technologies pick up the innovative momentum when earlier technologies start to lose it. Moore's Law is an example of this effect applied to the number of transistors in integrated circuits. Dr. Gannon showed how this same process has worked on a lot of common technologies we exploit every day. This effect can apply space weather technology, exemplified by Dr. Uccellini's slide showing the growth of SWPC product subscriptions, which is a proxy for the increasing number products and their accuracy and usefulness to users. In the commercial sector bootstrapping can be achieved through a variety of funding paths, including Small Business Innovative Research, Independent Research and Development, grants, and Cooperative Research and Development Agreements. Diverse contributions are important because we don't always know ahead of time what will work. The more ideas and technologies that are developed, the more likely effective bootstrapping can occur. The commercial sector has contributed diverse innovations in such areas as analytics, technologies, and satellites. Finally, feedback helps to build alignment between partners through cross-enterprise collaborations, R2O2R, and other mechanisms. Dr. Gannon completed her talk by highlighting the CPI magnetometer network as an example where diversity, bootstrapping, and feedback all came into play to result in an operational system built by the industry to address a problem defined by industry.

- **First Officer Rondeau Flynn**, Deputy Chairman, National Aeromedical Committee, Allied Pilots Association.

  First Officer Flynn represented over the over 15,000 American Airlines pilots in the Allied Pilots Association. He opened his presentation with a discussion of aviation radiation, a natural hazard that passengers and flight crews can experience at altitudes above 26000 feet. The radiation, including galactic cosmic radiation and solar energetic particles, can affect both avionics and human tissue. Aviation has the highest dose rate of any industry, including the commercial nuclear power industry. Exposure causes changes in cell DNA, and can lead to increased risk of cancer (skin, breast). Studies have suggested an increased risk of miscarriage and breast cancer, and a three-times higher incidence of a type of cataracts among pilots. While FAA and the national and international radiation protection organizations have recommended dose limits, there are no requirements in the U.S. to enforce those limits, and OSHA does not regulate U.S. aviation crew members (for radiation exposure). First Officer Flynn highlighted the need for research to establish both the radiation rates by altitude and latitude bands and the effects of long term low-dose radiation on human tissue. A cost-effective capability to sense radiation level in real time to support cockpit decision making is also needed. Further, 24-hour solar storm forecasting is required for improved flight planning, which would allow for route closures, delays, and additional fuel for flying at lower altitude or for greater flight distance. All this leads to three fundamental

principles of radiation protection: justification—some aircrew exposure is justified by the benefit of air travel; optimization—exposure should be kept as low a reasonably achievable; dose limits—total dose to an individual should not exceed limits. This leads to reasonable mitigation strategies: consider the type of flying (routes, aircraft type, monthly flight time, retirement plans, pregnancy), avoid flying above optimum altitude, limit medical imaging, get routine medical checks in the context of family history, have children early in the career, wear sunglasses, and track exposure. First Officer Flynn closed his presentation by showing some of the operational products that provide information on potential radiation exposure from SWPC and the Nowcast of Aerospace Ionizing Radiation System (NAIRAS).

- **Dr. Louis Lanzerotti**, Distinguished Research Professor of Physics, Center for Solar-Terrestrial Research at the New Jersey Institute of Technology

  Dr. Lanzerotti started with a slide depicting the various technologies that are affected by space weather. He went on to discuss the SWAG and the particular elements that academia (which he was representing) will and will not bring to the table. The strengths of academia include frontier research in theory, modeling, observation and measurement; awareness of advances around the world as they happen; and an enthusiasm to contribute to knowledge and applications. He allowed, however, that the academic sector often lacks a quantitative understanding of the needs of end users and specific system functions, and it tends to lack an understanding of the subtleties of trade secrets and intellectual property. Dr. Lanzerotti used a depiction of a satellite and the effects radiation can have on its various components to illustrate how the various sectors of the space weather enterprise contribute to understanding and mitigating those effects. He built on that illustration to discuss the current status of academic research. Over the past two decades a lot of frontier research has transitioned to operations and significantly enhanced support to users. However, today some research tends to be heavily concentrated in certain areas, and some does not have an obvious practical application at the end of the road. There has been an interesting trend for academic individuals to build corporations to supply commercial services based on their frontier research, including some members of ACSWA. These serve as great examples of effective R2O. Dr. Lanzerotti completed his presentation with an enthusiastic outlook on what he expects from the SWAG. It will significantly enhance and enlarge discussions and collaborations across the three sectors, and will allow for mutual growth in understanding of technical issues and frontier research. The result will be robust addressing of space weather needs: prediction, forecast, mitigation, retrospective analyses, and operations and design standards.

Q & A:

- *The space weather community faces a number of challenges (e.g., gaps in fundamental understanding of space weather processes, limitations in forecast capability, a lack of public understanding of space weather). How do you expect the SWAG to prioritize their activities given these challenges? Dr. Gannon: speaking for the end user and the academic communities, the SWAG should prioritize the end user requirements, but in the context of input from research underway in the academic and commercial sectors. Dr. Lanzerotti: the end user should be the starting point for prioritization, but the academic sector must make sure that the*

end user understands the status of related research and what may and may not be achieved. First Officer Flynn: There will be some overlap between user groups and their needs, and that may elevate certain priorities.

- *How does one get nominated to be part of the SWAG; what should be the considerations for selecting members of the SWAG from the user community? Mr. Murtagh (who was handling questions for the panel and is a SWPC employee): there will be meetings next week with the general council and others in NOAA to better understand how to put the advisory group together. Once that is determined, information will be provided to the community on the nomination process. Dr. Lanzerotti: ideally, it would be best to have people with a broad perspective. However, people in industry seem to be fairly concentrated in their area of endeavor. That creates a challenge. It will take a special effort to identify those that have a somewhat broader perspective who still are engaged enough to understand problems in some detail. Dr. Gannon: we know now what the issues are, but we don't know how that's going to change in the future. It's possible that the membership of the group will have to evolve over time. Dr. Lanzerotti: the length of service on the group may have to be flexible to make the group responsive to changing needs. Flight Officer Flynn: There will be some overlap between user groups and their needs, and that may elevate certain priorities.*
- *Will the advisory group be in a position to address needs of responders like FEMA or perhaps non-industry users like the DoD? Dr. Intriligator: All these aspects should be taken into account.*

Session 8: The Role of Space Weather in Creating a Safe, Stable, and Operationally Sustainable Space Environment

Moderator: **Dr. Brian Weeden**, Director of Program Planning, Secure World Foundation

Dr. Weeden opened the session by citing the growing concern about the 24,000 objects already in orbit around the earth ranging in size from a softball to a bus, and the increasing number of satellite operators launching additional constellations of satellites. The number of active satellites in orbit increased from about 2000 to 3200 over the past year, and there are plans to add tens thousands of satellites over the next decade. There are growing concerns about improving our space situational awareness (SSA) capability and starting to develop a space traffic management (STM) regime. This panel will discuss what's happening with SSA and STM, and the role that space weather will have in supporting those capabilities. Dr. Weeden introduced the panelists and invited them to provide an opening statement.

- **Dr. Diane Howard**, Chief Counsel, Office of Space Commerce, Department of Commerce

  Dr. Howard pointed out that space weather data was included as the initial data set in the STM data repository being built to support STM, a testament to the importance of space weather. Space Policy Directive-3 (SPD-3—the White House directive that addresses STM), speaks of SSA in terms of the operating environment, and space weather is certainly part of that environment. SPD-3 defines SPM as planning, coordination, and on-orbit synchronization of activities to enhance the safety, stability,

and sustainability of operations. Dr. Howard invited the space weather enterprise to participate in the development of the repository by providing guidance in commercial applications development, the use of standards, and ensemble modeling analysis. SPD-3 tells us that we should be developing an STM framework that consists of best practices, technical guidelines, safety standards, behavioral norms, prelaunch risk assessment, and on-orbit collision avoidance services. Obviously, that will require participation across the enterprise.

- **Dr. Jeff Thayer**, Space Weather Technology, Research, and Education Center Faculty Director and Professor, Aerospace Engineering Sciences, University of Colorado at Boulder

  Dr. Thayer started by introducing the Space Weather Technology, Research and Education Center, which brings together space weather actives underway across the campus of the University of Colorado. One of the areas of study is LEO space domain science, which incorporates SSA and STM. He illustrated the challenge of forecasting orbits by showing variations in neutral densities by latitude during quiet and active solar phases from the GRACE satellite, and then the same data on plasma densities from the Swarm satellite. Variations during the quiet phases ranged from 50 to 100%, and during active phases up to a factor of 8. The challenge, then, is to forecast these changes so that operators can reduce the error ellipsoid of satellite positions. Dr. Thayer proceeded to highlight the need for more operational (as opposed to science-oriented) observations of the LEO space environment. He introduced the concept of symbiotic sensors—using information from mission systems to back out space domain information—and cited several examples. This approach could supply the type of global, high-density observations we need to support SSA and STM. He wrapped up his comments by detailing the work that is going at the Space Weather Center.

- **Dr. Moriba Jah**, Associate Professor, Department of Aerospace Engineering and Engineering Mechanics, University of Texas at Austin

  Dr. Jah stated that the goal is be able to make decisions that insure safety, security, and sustainability of objects in space. We are dealing with an extraordinarily complex system, and we're looking for enough structure amid the chaos to be able to manage it. One approach is to link the space environment phenomenology with the objects into a big data problem to provide prescriptive analytics—the ability to not only to know what is going to happen, but then prescribe solutions to avoid bad outcomes. In order to do that, we need to understand the causal relationships between the objects and their environment. However, debris (which is most of the stuff in orbit) does not provide *in situ* measurements of the environment, and we don't know much about how it behaves. So the objective is to find hidden information is very large amounts of seemingly unconnected data. Toward this end, the FAA funded AstriaGraph, an open, transparent, and crowdsourced space traffic and environment monitoring and awareness system. It brings in data from multiple sources, and organizes and curates in a way that helps to link it so as to discover hidden information that will help us understand and manage the situation.

- **Mr. Steph Earle**, Acting Deputy Division Chief, Office of Commercial Space Transportation, Federal Aviation Administration

Mr. Earle pointed out that FAA protects public land, sea, space, and air impacted by commercial space transportation issues. It's important to recognize that launch operations are different from space operations. FAA looks at three areas associated with space launch, traffic, and weather—direct physic impacts, human health, and environmental effects on safety during orbital insertion.

Q & A:

- *We're digging ourselves a hole in terms of the amount of stuff in orbit. Is it feasible to limit how many additional objects we allow to be launched into space? Is the government planning to do something about this problem? Dr. Weeden: U.S. government oversight of commercial activities is assigned to three agencies. DOC licenses remote sensing satellites and is tasked with the broader view of SSA and STM. FAA licenses commercial launches and reentries, and the FCC licenses commercial use of spectrum. So FCC is the main organization dealing with managing large constellations of communication satellites, and is currently in the hot seat on these issues. The Commission has been involved in an on-going rule-making process since 2018 to figure out what if any additional debris mitigation requirements are needed on top of existing practices. Dr. Howard: The goal of FCC is to make sure that what they license is responsible. We're working on trying to be able to help answer the questions the regulators ask during these processes. Mr. Earle: The question is "When is enough, enough?" We're certainly seeing impacts from congestion, but it's not clear we've reached the limit of what we can put in the available space. Should we step in and constrain the further use of space, or should be let it "self-adjust?" Dr. Jah: we know that systems naturally reach equilibrium. Right now, however, we're launching satellites at such a rate that we're not allowing the environment to inform us as to what equilibrium looks like. We should agree to a globally accepted definition of orbital carrying capacity. That could be defined as the point where our decisions and subsequent actions can no longer prevent the loss, disruption, or degradation of a service or activity beyond some given percentage over a given time. Once we have that, we will have the basis to manage that capacity. Dr. Thayer: orbital carrying capacity will be defined at any time by what we know about the orbits of the objects. We can increase that capacity by improving our ability accurately predict positions of objects. Dr. Weeden: one of the problems is that we don't effectively use orbital space—we tend to put most objects into a limited number of very useful orbits.*
- *Why is the Space Weather Center so focused on LEO rather than MEO or GEO. Dr. Thayer: That has to do with the number of satellites in LEO and the variability of the drag forces that modify their orbits. The other orbital areas are affected in other ways by space weather, and the Center is working those issues, too.*
- *Is AstriaGraph publicly available, and what does it do? Dr. Jah: It is publically available. When we talk about going from observations to taking actions, we think about the OODA loop—Observe, Orient, Decide, Act. AstriaGraph supports that process by providing the first two elements. It has multiple sources of observations, which it orients by mapping those into and environment where users with different needs can discover what they need. With that, users can decide and act. Dr. Weeden: it's interesting that there are often multiple positions for a given object*

from different sources, which can provide useful information. Dr. Howard: the use of ensembles, discussed earlier, could be very useful in dealing with this type of information.

- *Where is DOC on getting congressional authority and funding to implement SPD-3? Dr. Howard: Commerce can provide SSA data, but has only broad and vague regulatory authority. A bill providing that authority has passed the Senate and is now in the House.*
- *Should we be thinking of developing something like buoys in space like we have in the ocean? Dr. Thayer: we definitely need to make better measurements in space and time. We talked about backing out information from how satellites perform their mission tasks, but instruments have become small enough that fleets of ride-share sensors are feasible. This additional data should allow us to move from nowcasting to forecasting elements that support STM.*
- *What is Collision Avoidance Analysis (COLA) and how does it work? Mr. Earle: If a planned launch is going to create a conflict with an existing object in space, FAA works with the applicant to conduct a COLA. They determine the trajectory every minute for a three-hour window and look for window that won't result in a conflict. The effects of drag are included in that analysis, and that's where space weather comes into the process. The government is doing the COLA analysis. The 18th Space Control Squadron (18SPCS) is a key partner in this process because they have a complete catalog with the most current information on the position of objects.*
- *Can you talk about OADR? Is it going to include commercial space weather products? Dr. Howard: Establishment of an Open Architecture Data Repository (OADR) for SSA was mandated by SPD-3. This involves developing standards and protocols so that the repository includes such features as data integrity measures to ensure accuracy and availability, data standards to ensure sufficient quality from diverse sources, measures to safeguard proprietary or sensitive data, the inclusion of satellite owner-operator ephemerides to provide current and planned orbital location, and standardized formats to enable development of applications to leverage the data. It will include commercial data sets as available, as well as international data.*
- *In terms of the SSA and STM worlds, where do we need more help? Dr. Thayer: LEO is strongly driven by energy from the sun (it's not as chaotic as the terrestrial atmosphere). We need to get more accurate energy inputs, and that involves better observations and forecasts of solar activity. Dr. Jah: Too often, we have to make decisions about objects that react to phenomenologies on the timescale of minutes using three-hour average data. We need to get data on the timescales that align with the timescale of the behavior of objects. We need to figure out a way to curate and link the data such that they can be queried to do analyses. We need to get better at defining uncertainty, including what is endemic to the system and what is random. While our space weather models have improved enormously, we need to figure out how to implement them in a more pragmatic, responsive way to deal with orbital positions of objects. Finally, recognizing that debris does not transmit*

information about itself, we need to better understand its behavior so we can routinely and accurately determine the risk it poses.

- *Are other countries doing things similar to COLA? Mr. Earle: launch collision avoidance is one of the long-term sustainability guidelines approved by the UN. Countries that don't have a robust tracking capability provide their information to the 18SPCS, and they process it. Russia and China don't share much information, but we would like to have that information to enhance the safety of our operations. Japan and ESA do provide information.*
- *How does spectrum management play into SSA and STM: Dr. Weedon: the longest standing STM effort has been to manage geostationary orbit for communications. The orbit had been divided into segments of about a tenth of a degree (or 70km) where satellites can be located. This is to minimize electromagnetic interference. Because the FCC regulates the commercial portion of the spectrum, they have some ability to impact the process.*

Session 9: Space Weather Support for Human Space Flight

Moderator: **Dr. John Allen**, Program Executive, Crew Health and Safety, Human Exploration and Operations Mission Directorate, HQ NASA

Dr. Allen pointed out that while much of the conversation over the last two days has been geared toward protecting infrastructure and activities on the surface of the earth from solar events, there have also been references to the need to protect assets that are exploring space, both equipment and people. That's important because the Artemis program is moving forward, and a few days ago four astronauts docked at the International Space Station (ISS), culminating the first operational manned space launch from the U.S. since the Space Shuttle was retired. These are exciting times for human space flight, both from the NASA perspective and the commercial perspective. Both in human exploration of space and in commercial exploitation of space it will be increasingly important to protect the people who are exposed to the elements. Dr. Allen introduced the panels who will address how we plan to do that.

- **Mr. Eddie Semones**, NASA Space Radiation Analysis Group, Johnson Space Flight Center

  Mr. Semones set the stage for his presentation by returning to the Apollo era, presenting a slide showing radiation dose estimates for solar particle events during the Apollo 7 through 12 missions and noting that none of the events occurred during the missions. He also covered the space environment rules NASA applied during Apollo, which set a paradigm that is still useful (although thresholds have changed). He then fast-forwarded to the present to discuss how NASA deals with solar energetic particle (SEP) events on the ISS, using data from the SWPC to decide whether to move astronauts to areas in the station with better shielding. That process typically evolves over several hours and involves international cooperation. However, not all everts allow for several hours to respond. Mr. Semones highlighted, by way of example, the Fast January 2005 event, during which high energy particles arrived at the earth within minutes after a solar flare, with just the flare itself as a precursor. This event illustrated the importance of being ready to respond immediately to potential threats. He noted that, like the

Apollo missions, Artemis will be conducted during solar max, which means we must be prepared to deal with potentially dangerous solar events. The 2005 event also highlighted the difference between the threat in interplanetary space and LEO. It wasn't detected at the ISS until almost 2 days later. Artemis won't have that luxury of time—the mission response will have to be immediate, which will require as much forecasting as possible and rapid data processing and analysis to support nowcasting. NASA is working on tools that will take the SWPC forecasts and process them into rapid, automatic decisions to support Artemis operations during SEP events. The tools are being developed by the CCMC and the Solar Radiation Analysis Group (SRAG), and will be called the Integrated Solar Energetic Proton (ISEP) Event Alert/Warning System. Mr. Semones presented the operational schema for Artemis missions, which showed how ISEP fits into the decision-making process, and the concept of operations and scenarios related to SEP events. He showed a cut-away of the Orion capsule indicating where the particle monitoring instruments are mounted and how equipment can be repositioned within an hour to provide shielding for the astronauts. Mr. Semones finished his presentation by highlighting the work needed to finish preparations to support Artemis and build the foundation to support missions to Mars.

- **Dr. James Spann**, Chief Scientist, Heliophysics Division Chief Scientist, HQ NASA

  Dr. Spann started his presentation by reiterating the NASA Space Weather Strategy's 6 goals that Dr. Fox introduced in her talk yesterday. The first three goals are the things that that Science Mission Directorate does intrinsically—observe, analyze, and predict. The 4th goal—transition—involves helping move the technology that NASA has developed into operations in other agencies. This talk will be focused on the 5th goal—supporting robotic and human exploration. To support human exploration NASA would like to develop Earth-independent observational and modeling capabilities needed for on-board space environment forecasting on long-duration crewed missions. This would eliminate reliance on real-time communications with the Earth. Gateway will be the pathfinder for this effort. NASA has developed the Heliophysics Environmental and Radiation Measurement Experiment Suite (HERMES) for this purpose, and it will work with ESA's Radiation Sensor Array (ERSA), also on Gateway, toward that end. Moving on to the 6th goal, Dr. Spann explained that the partnering effort will include a Space Weather Advisory Council under Heliophysics Advisory Committee. The Council will include membership from the user and commercial sectors. In the international environment, NASA is very involved in the United Nations Committee on the Peaceful Uses of Outer Space and individual nations' space agencies, including ESA, and the Canadian Space Agency. With the discussion of NASA's space weather strategic goals as background, Dr. Spann moved on to the details of supporting human space flight. He briefly described the Gateway, then went on to discuss HERMES in detail. HERMES will comprise four instruments—an electron spectrometer, and ion spectrometer, and ion and electron telescope, and magnetometers—which will measure the solar wind environment in conjunction with observations from two other spacecraft that are already orbiting around the moon. Dr. Spann concluded his presentation by emphasizing that while Artemis is about putting the first woman and the next man on the moon, and eventually establishing operations on the moon, it embodies a variety of science objectives and will present unique opportunities to advance the understanding of space weather.

- **Dr. Juha-Pekka Luntama**, Head of Space Weather Office, European Space Agency

  Dr. Luntama opened his remarks by introducing a new ESA effort called the Space Safety Programme (S2P), which protects the Earth, humanity, and assets in space and on Earth from dangers originating in space. SSP replaced an earlier program call Space Situational Awareness (SSA). S2P addresses space debris and the asteroid threat as well as space weather. One difference between SSA and S2P is that the new program includes active measures to reduce risk (e.g., debris removal, asteroid deflection). It is an international collaboration, so ESA is working with NASA on these challenges. Dr. Luntama detailed the objectives of the space weather part of S2P, targeted at 2030, and emphasized the importance of tailored, actionable space weather products. ESA's role is very similar to NASA's—they develop, verify, and test new capability, then help transition it operations. ESA works through its member states, involving over 50 entities in Europe. Moving on to human space flight services, he explained the user requirements, which were defined in 2009 and are being revised at this time. The requirements include those that are associated with space operations in general and those that are specific to human space flight. He then showed their portal to illustrate the status of ESA's capability to meet the requirements. Dr. Luntama indicated that ESA does a fairly good job of meeting the general requirements. The requirements to support human space flight are addressed mostly by human forecasters, as opposed to automation. ESA also does a fairly good job at forecasting solar activity, all-quiet conditions, and radiation doses. However, they are still working on forecasting the onset of SEP events. To address that deficiency, ESA initiated the Advanced Solar Particle Events Casting System (ASPECS) in 2017, which is part of the SEP Advanced Warning System (SAWS). ESA is also working on a planning tool call Human Interplanetary Exploration Radiation Risk Assessment System. Dr. Luntama went on to talk about collaborative monitoring systems in space, then discussed the ERSA system for the Artemis Gateway that Mr. Semones had mentioned in his earlier presentation. The sensors on ERSA include two dosimeters, three radiation monitors, and 2 magnetometers. He concluded his briefing by providing information on the sensors on the Lagrange Mission to L5.

Q & A:

- *In the context of human space flight, how do you see involvement with the commercial sector benefiting you, and what benefits will the commercial sector garner? Dr. Spann: We will continue to provide information to help the commercial sector to operate and to diagnose problems that may be related to space weather. Meanwhile, the commercial sector is providing components of the system to return to the moon (e.g., the Gateway). In addition, we should be exploring how to exploit, for gathering space weather observations, the large number of small satellites the commercial sector is placing on orbit. Mr. Semones: the commercial sector reaps the benefits of what we've learned and the information we can supply, and as the commercial sector puts more humans into space, that benefit will grow. Dr. Luntama: ESA is working closely with the private sector to promote payloads hosted on commercial vehicles. They are in discussions on putting radiation sensors on Lunar Pathfinder, a commercial initiative that will provide data services via communications links to lunar assets from lunar satellites.*

On the flip side, ESA uses the data from hosted payloads to provide better information to the commercial sector.

- *Did the Apollo dose limit account for shielding from spacecraft and spacesuits? Mr. Semones: yes.*
- *Can you elaborate on the potential collaboration with Canada on the Tundra mission? Dr. Spann: Canada has been developing a concept for flying a weather satellite in a molniya or similar highly-elliptical orbit to provide better high-latitude data. NOAA and NASA are discussing with them the possibility of including space weather sensors on the satellite.*

Session 10: SWEF Summary and Wrap-Up

Mike Bonadonna reviewed the highlights of the second day of the SWEF. The Space Weather Advisory Group is a key aspect of the PROSWIFT Act, and will provide a tremendous opportunity for the enterprise. We expect that the SWAG will be able to participate in the next SWEF. The session on SSA and STM provided a fascinating look at the nexus between "old space" and "new space," between technology and policy, and between old and new ways of deriving information from data. And, of course, any discussion of human space flight is interesting, but our national momentum toward both LEO and interplanetary operations made that session particularly compelling. Mr. Bonadonna pointed out that SWEF participants can review the last two days' events by consulting the OFCM web page, where they will find the final agenda now, the presentations that have been approved for public release (most of them) shortly, and a summary report within the next month or so. He wrapped up the forum by thanking those responsible for making it happen. He thanked Congressman Ed Perlmutter and Mo Brooks for their participation, as well as all the moderators and panelists. He also thanked the organizations behind the effort—the Secure World Foundation, the American Commercial Space Weather Association, and the National Space Weather Partnership. Finally, he thanked the SWEF Organizing Committee for putting the forum together over the last six months, and the OFCM staff, which managed the technology behind a nearly seamless two-day virtual event. Mr. Bonadonna closed the session by thanking all the participants and expressing the hope that when we meet for the next SWEF we can all be in the same room.

2020 Space Weather Enterprise Forum Agenda

"Implementing Space Weather Legislation, Strategy, and Plans to Protect the Nation"

November 19-20, 2020

November 19, 2020

Session 1: Welcome to SWEF 2020

10:00 am	**Dr. Michael Bonadonna**, Executive Secretary, Space Weather Operations Research and Mitigation (SWORM) Interagency Working Group and Director, Office of the Federal Coordinator for Meteorology (OFCM) **The Honorable Edward Perlmutter**, United States House of Representatives, Colorado's 7th Congressional District

Session 2: Implementing an Integrated Strategy -Sustaining and Advancing Critical Space Weather Capabilities

10:30 am	**Moderator: Dr. Aaron Miles**, Principal Assistant Director, National Security and International Affairs, OSTP **Panelists:** • **Dr. Louis Uccellini**, National Oceanic and Atmospheric Administration (NOAA) Assistant Administrator for Weather Services and Director, National Weather Service • **Bob Kolasky**, Director, Cybersecurity and Infrastructure Security Agency, National Risk Management Center, DHS • **Dr. Chris Cannizzaro**, Director of Critical Infrastructure, National Security Council **Panel Discussion**

11:40 am Lunch Break

Session 3: Understanding and Preparing for Extreme Space Weather Events

12:25 pm	**Moderator: Dr. Mangala Sharma**, Program Director, Space Weather Division of Atmospheric and Geospace Sciences (NSF) **Panelists:** • **Dr. Geoff Reeves**, Senior Scientist, Space Sciences and Applications Group, Los Alamos National Laboratory • **Ms. Kenyetta Blunt**, Chief, Recovery Planning Branch, Federal Emergency Management Agency (FEMA) • **Mr. Lindley Johnson**, Planetary Defense Officer and Program Executive, Planetary Defense Coordination Office (NASA) **Panel Discussion**

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

Session 4: Improving Research-To-Operations; Operations-To-Research Capabilities

1:35 pm	**Moderator: Dr. Michael Wiltberger**, Geospace Section Head (NSF) **Panelists:** • **Lt Col Omar Nava**, Chief of Space Weather Integration, Directorate of Weather, Headquarters United States Air Force, HQ USAF A3W) • **Dr. Michelle Cash**, Space Weather Prediction Center (NOAA) • **Dr. Nicky Fox**, Director, Heliophysics Division (HQ NASA) **Panel Discussion**

Session 5: Day Summary and Wrap up

2:45 pm	**Dr. Michael Bonadonna**, Executive Secretary, Space Weather Operations Research and Mitigation (SWORM) Interagency Working Group and Director, Office of the Federal Coordinator for Meteorology (OFCM)

November 20, 2020

Session 6: Day-2 Opening Remarks

10:00 am	**Mr. Michael Bonadonna**, Executive Secretary, Space Weather Operations, Research, and Mitigation (SWORM) Interagency Working Group and Director, Office of the Federal Coordinator for Meteorology (OFCM) **The Honorable Mo Brooks**, US House of Representatives, Alabama's 5th Congressional District

Session 7: Role of the Space Weather Advisory Group

10:30 am	**Moderator: Dr. Devrie Intriligator**, Director, Space Plasma Laboratory, Carmel Research Center, Inc. and American Commercial Space Weather Association Executive Committee • **Dr. Jennifer Gannon**, Strategic Director, Computational Physics, Inc. and American Commercial Space Weather Association Executive Committe**e** • **First Officer Rondeau Flynn**, Allied Pilots Association, Deputy Chairman, National Aeromedical Committee, Pilot Occupational Health Committee • **Dr. Louis Lanzerotti**, Distinguished Research Professor of Physics, Center for Solar-Terrestrial Research at the New Jersey Institute of Technology **Panel Discussion**

11:40 am Lunch Break

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Session 8: The Role of Space Weather in Creating a Safe, Stable, and Operationally Sustainable Space Environment

12:25 pm	**Moderator: Brian Weeden,** Director, Director of Program Planning Secure World Foundation • **Dr. Diane Howard**, Chief Counsel, Office of Space Commerce, Department of Commerce • **Mr. Steph Earle**, Acting Deputy Division Chief, Office of Commercial Space Transportation, Federal Aviation Administration • **Dr. Moriba Jah**, Associate Professor, Department of Aerospace Engineering and Engineering Mechanics, University of Texas at Austin • **Dr. Jeff Thayer**, Space Weather Technology, Research, and Education Center Faculty Director and Professor, Aerospace Engineering Sciences, University of Colorado at Boulder **Panel Discussion**

Session 9: Space Weather Support for Human Space Flight

1:35 pm	**Moderator: Dr. John Allen.** Program Executive, Crew Health and Safety, Human Exploration and Operations Mission Directorate, NASA HQ • **Dr. Eddie Semones**, NASA Space Radiation Analysis Group, Johnson Space Flight Center • **Dr. James Spann**, Chief Scientist, Heliophysics Division Chief Scientist, HQ NASA • **Juha-Pekka. Luntama**, Head of Space Weather Office, European Space Agency **Panel Discussion**

Session 10: SWEF Summary and Wrap up

2:45 pm	**Dr. Michael Bonadonna**, Executive Secretary, Space Weather Operations Research and Mitigation (SWORM) Interagency Working Group and Director, Office of the Federal Coordinator for Meteorology (OFCM)

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