

**Space Weather Advisory Group (SWAG)**

Public Meeting

Virtual

*Meeting Minutes*

Monday, March 20, 2023

11:00 AM – 3:00 PM

**Meeting Attendees**

**Committee**

***Nongovernmental End User Representatives***

Dr. Tamara Dickinson, Committee Chair, Science Matters Consulting  
Mr. Mark Olson, North American Electric Reliability Corporation - not present  
Mr. Michael Stills, United Airlines (retired) - not present  
Mr. Craig Fugate, Bent Ear Solutions  
Dr. Rebecca Bishop, Aerospace Corp.

***Commercial Sector Representatives***

Dr. Jennifer Gannon, Computational Physics, Inc.  
Dr. Conrad Lautenbacher, GeoOptics, Inc.  
Dr. Seth Jonas, Lockheed Martin  
Dr. W. Kent Tobiska, Space Environment Technologies  
Dr. Nicole Duncan, BAE Systems

***Academic Community Representatives***

Dr. Tamas Gombosi, University of Michigan, Ann Arbor  
Dr. Delores Knipp, University of Colorado, Boulder  
Dr. Scott McIntosh, National Center for Atmospheric Research  
Dr. Heather Elliott, Southwest Research Institute  
Dr. George Ho, Johns Hopkins University Applied Physics Laboratory

***Designated Federal Officer***

Dr. Jennifer Meehan, National Space Weather Program Manager, National Weather Service

**Invited Guests Present**

Ms. Amy Macpherson, National Weather Service  
Mr. William Murtagh, National Weather Service  
Dr. Omar Nava, United States Air Force  
Dr. Mangala Sharma, National Science Foundation

**Members of the Public Present**

Tom Berger  
Brent Blevins  
Arthur Charo  
Lamont DiBiasi  
Jeff Foust  
Katherine Garcia-Sage  
Carl Gelderloos  
Austin Gibbons  
Jennifer Hensley  
Tristram Hyde

Devrie Intriligator  
Eva Lipiec  
Victor Lozano  
Griffin Reinecke  
Richard Rogers  
Tamitha Skov  
Michael Wiltberger  
James Wolfenbarger  
Brian Cavanaugh  
Sylvie Espinasse  
Antti Pulkkinen  
Dana Turse

## **Meeting Minutes**

### **11:00-11:05: Welcome (Dr. Jennifer Meehan, SWAG DFO)**

Dr. Meehan welcomed everyone to the fifth Space Weather Advisory Group (SWAG) meeting, in which SWAG continued discussion on how best to implement Section 60601 of the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act. The Space Weather Operations, Research and Mitigation (SWORM) White House subcommittee selected non-governmental members in 2021 for a three year term.

SWAG members that were present stated their names and institutions.

### **11:05-11:15: Opening Remarks and Recap of Meeting 4 (Dr. Tamara Dickinson, Science Matters Consulting, and Chair, SWAG)**

Dr. Dickinson gave an overview of what was discussed at the first hybrid January 2023 meeting, which focused on the recommendation report, and discussed progress on findings and recommendations development.

Dr. Dickinson reviewed the agenda for this meeting, which included:

- Overarching Recommendations
- Ground-Based and Airborne Sensors and Networks
- In-Space Architectures and Space-Based Observations
- Data and Computing Infrastructure for Space Weather Operations
- Space Weather Risk to Evolving Infrastructure Systems and Services
- Improving Benchmarks, Metrics, and Scales for Space Weather End-Users
- Economic Assessments on The Costs of Space Weather and the Value of Forecasting and Mitigation
- Promote Focused and Continued Engagement Across Industry and Government Space Weather Stakeholders
- Other Key Findings and Recommendations
- Priority Recommendations
- Committee Discussion and Approval of Report

**11:15-11:30: Progress Since Meeting 4 (Dr. Tamara Dickinson, Science Matters Consulting, and Chair, SWAG)**

Dr. Dickinson discussed the background of the report which included:

- Input from SWAG members, implementation plan progress report, and national space weather policy and statute
- A walk through the recommendations, discussion and findings
- The space weather enterprise is composed of government, commercial, and academic sectors
- Purpose of this document is to give input to SWORM, Congress and Enterprise
- Briefings will be given to SWORM and other interested stakeholders
- A deeper dive is possible if the SWORM requests it

**11:30-11:45: Overview of today's meeting (Dr. Tamara Dickinson, Science Matters Consulting, and Chair, SWAG)**

Dr. Dickinson discussed the agenda and how the SWAG will step through the process of the findings and recommendations to be included in the report.

- Overarching Recommendations
- Ground-Based and Airborne Sensors and Networks
- In-Space Architectures and Space-Based Observations
- Data and Computing Infrastructure for Space Weather Operations
- Space Weather Risk to Evolving Infrastructure Systems and Services
- Improving Benchmarks, Metrics, and Scales for Space Weather End-Users
- Economic Assessments on The Costs of Space Weather and the Value of Forecasting and Mitigation
- Promote Focused and Continued Engagement Across Industry and Government Space Weather Stakeholders
- Other Key Findings and Recommendations
- Priority Recommendations
- Committee Discussion and Approval of Report

**11:45-12:00: Priority and Overarching Recommendations (Dr. Tamara Dickinson, Science Matters Consulting, and Chair, SWAG)**

Dr. Dickinson discussed the priority and overarching recommendations. The report will have more information on each of these topics.

R.1.1 Fund the Federal Space Weather Enterprise

R.2.1 Create and fund an applied research program office for space weather within NOAA to coordinate, facilitate, promote, and transition applied research across the national space weather enterprise.

R.2.2 Develop NOAA strategies to ensure agency-wide coordinated implementation of PROSWIFT and their national space weather policy responsibilities

R.2.3 Expand NOAA R2O2R functionality to enable the transition to full operations

R.3.1 Ensure OSTP staffing and White House led prioritization coordination across the national space weather enterprise

R.4.1 Consider space weather in the context of broader national risk

R.5.1 Protect space weather sensors from spectrum interference

**12:00-12:15: Ground-Based and Airborne Sensors and Networks (Dr. Jennifer Gannon, CPI, SWAG Member)**

Dr. Gannon discussed the recommendations for ground-based and airborne sensors and networks. The report will have more information on each of these topics. Ground-based terminology is used for both ground and air-based sensors.

R.6.1 Assess and publish the prioritization of ground-based sensors needed for current and future space weather products

R.6.2 Provide long-term support for operational ground-based sensors and networks

R.6.3 Fund the transition of NSF research sensors and networks to operations

R.6.4 Coordinate support for ground-based sensors and networks that are essential to space-based missions

R.7.1 Expand the use of CRADAs to improve collaboration across the academic and commercial sectors

R.8.1 Prioritize the addition of underutilized, existing real-time magnetometer data stream over new MT survey campaigns

Dr. Dickinson opened up the floor for discussion among SWAG members:

- Dr. Bishop commented that R.6.3 should be done regardless if the products are ready to use that data. We can't wait to transition because we will lose this infrastructure. Dr. Gannon agreed. This comment will be captured in the report text.

**12:15-12:30: In-Space Architectures and Space-Based Observations (Dr. Nicole Duncan, Ball Aerospace, SWAG Member)**

Dr. Duncan discussed the recommendations for in-space architectures and space-based observations. The report will have more information on each of these topics.

R.9.1 Revise the National Space Weather Strategy and Action Plan to broaden service coverage of additional space environments; motivated by increase in national need

R.9.2 Provide baseline operational space weather services beyond near-Earth; need for services

R.9.3 Support and fund additional space weather data and services beyond near-Earth; need to be supported and funded

Dr. Gannon asked what is considered a baseline operation. Dr. Duncan responded that it was intentionally left more open and top-level. Dr. Bishop agreed to leave it open ended because we don't yet know what services are required by the different sectors. Dr. Duncan clarifies that this chapter is in addition to the needs of LEO.

R.10.1 Fund NASA foundational space weather research missions

R.10.2 Use a coordinated approach to develop and deploy foundational space weather missions

R.10.3 Establish O2R traceability in the NASA mission formulation process

R.10.4 Develop a prioritization of space-based sensors to enhance space weather products

Dr. Gannon asked for an example of a foundational space weather mission. Dr. Duncan responded with the example of IMAP, looking at outer reaches of the solar system and the space weather connection. Lots of overlap in various missions. Dr. Gombosi asked about GDC. Dr. Duncan responded that there is a broad range with lots of overlap. Dr. Tobiska gave his opinion that GDC should be continued and considered a foundational mission.

R.11.1 Opportunistically deploy more space weather sensors.

R.11.2 Fly space weather particle sensors on every U.S. Government procured space vehicle

R.12.1 Sustain resilient approaches to ensure continuity of in-space operational space weather observations

Dr. Bishop commented that each recommendation should be taken in context with all other recommendations. Dr. Knipp R.11.2: The NWS has worked agreements with U.S. airlines for weather observations, and it is well worth pursuing on space vehicles.

**12:30-12:45: Data and Computing Infrastructure for Space Weather Operations (Dr. Delores Knipp, UC Boulder, SWAG Member)**

Dr. Knipp discussed the recommendations for data and computing infrastructure for space weather operations. The report will have more information on each of these topics. Dr. Knipp noted that we've seen explosive growth but remain data starved.

R.13.1 Fund, formalize, and expand the NOAA space weather prediction testbed

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

R.13.3 Improve interagency coordination of models and data

R.13.4 Promote and prepare for the use of AI/ML algorithms as a complement to traditional empirical and physics-based models

R.13.5 Continue to identify and release novel and underutilized data sets that improve space weather products

R.13.6 Promote career pathways for interdisciplinary technologists supporting the space weather enterprise

Dr. Tobiska commented that this is a great opportunity to look across the entire enterprise to be sure to include underutilized datasets. Dr. Bishop commented that interdisciplinary technologists are very important, especially to maintain partnerships and not work in isolation.

Dr. Tobiska commented that the SWPC aviation testbed was a great example of communication of space weather effects across the entire aviation industry.

**12:45-1:00: Break**

**1:00-1:15: Improving Benchmarks, Metrics, and Scales for Space Weather End-Users (Dr. Seth Jonas, Lockheed, SWAG Member)**

Dr. Jonas discussed the recommendations for improving benchmarks, metrics, and scales for space weather end-users. The report will have more information on each of these topics. As technology and demand for space weather information increase, updates to scales and benchmarks need to be done.

R.14.1 Coordinate benchmark development or improvement with industry

R.14.2 Promote industry participation in workshops and meetings to inform the mitigation of space weather hazards

R.14.3 Use multiple approaches to validate benchmarks

R.15.1 Identify and prioritize the development of key space weather metrics

R.15.2 Update and expand NOAA space weather scales

R.15.3 Maintain historical space weather indices

Dr. Tobiska mentioned that R.15.3 is important to continue their legacies. There are tens of millions of code already used in operations that use the existing indices. This will be included in the report. Mr. Fugate commented that we have a lot of variability in the scales as there are. Focusing on and adding the impacts will be important within the revision of the scales. Dr. Duncan asked for an example in another sector of an impact. Mr. Fugate brought up the hurricane scales that don't address all impacts of hurricanes. The NWS started focusing on the individual impacts and not just the category of the hurricane. The NWS facilitated that shift based on feedback from users. Dr. Gannon amplified that it really needs to come back to involving the end-user needs and feedback. Dr. Gombosi suspects that the industry is not ready for impact-based forecasts. Mr. Stills wondered about the complications of the scales specifically in the aviation industry. Dr. Jonas expressed that there are roles of SWPC scales, and roles of industry response to the scales. Dr. Elliott mentions that prioritization is key. Dr. McIntosh comments that space weather scales don't have the maturity to categorize impacts because we do not have the observations and data. Mr. Fugate responded that there is still a need and we shouldn't wait for science to catch up. Dr. Jonas emphasized that we will need to capture Mr. Fugate's points in the report.

**1:15-1:30: Space Weather Risk to Evolving Infrastructure Systems and Service (Dr. Jennifer Gannon, CPI, SWAG Member)**

Dr. Gannon discussed the recommendations for space weather risk to evolving infrastructure systems and service. The report will have more information on each of these topics.

- R.16.1 Develop and enduring process to understand evolving infrastructure needs
- R.16.2 Leverage industry assessments and applications of magnetotelluric data and Geomagnetically-induced current data to improve Earth conductivity models and geomagnetically-induced current assessment tools
- R.17.1 Promote the development of vulnerability assessments by sector owners and operators
- R.17.2 Prioritize addressing space weather risks in sectors other than electric power and aviation
- R.17.3 Address interdependencies of and cascading risks to critical infrastructure

Dr. Jonas comments that one thing that was recognized was the rate at which and domains at which the infrastructure is evolving to and the need of the user base evolving. Infrastructure vulnerability has moved from ground to ground and space based. The recommendations here will help inform the process as we move forward. Dr. Elliott mentioned that we are relying on more assets and technology more vulnerable to space weather that haven't been through a strong solar storm. These recommendations support increasing our resilience.

**1:30-1:45: Economic Assessments on The Costs of Space Weather and the Value Of Forecasting and Mitigation (Dr. Delores Knipp, UC Boulder, SWAG Member)**

Dr. Knipp discussed the recommendations for economic assessments on the costs of space weather and the value of forecasting and mitigation. The report will have more information on each of these topics. This topic is outside the community with which SWAG members typically interact. Dr. Knipp notes that all aspects of value should be looked at from forecasting to end-user mitigation.

- R.18.1 Quantify the societal benefits for addressing risk from space weather by performing national-level and industry-wide economic assessments
- R.18.2 Develop and curate data necessary for effective economic assessments
- R.18.3 Broaden the scope of economic assessments
- R.18.4 Engage additional stakeholders for economic assessments

Dr. Jonas highlighted that industry wide engagement on these recommendations is very important for understanding the need, especially engaging the end users. Dr. Knipp added that the value of the forecasting is needed. Dr. Jonas commented that these economic assessments will help us quantify risks. Dr. Tobiska commented that we should highlight a bullet that includes what the economic impacts are due to inaccurate forecasts. Dr. Knipp stated that this is included in the report. Dr. Elliott also commented that the all-clear aspect of the forecast should be addressed.

**1:45-2:00: Promote Focused and Continued Engagement Across Industry and Government Space Weather Stakeholders (Dr. Rebecca Bishop, Aerospace Corp, SWAG Member)**

Dr. Bishop discussed the recommendations for promoting focused and continued engagement across industry and government space weather stakeholders. The report will have more information on each of these topics. This will need to be a partnership across the industry, government, and stakeholders.

R.19.1 Enhance distribution of space weather products; dissemination has been difficult

R.19.2 SWORM should increase transparency by ensuring the publication of foundational documents, studies, and policies.

R.20.1 Develop standing MOUs or MOAs across and between all SWORM agencies

R.21.1 Develop and implement broader participation in tabletop exercises

Dr. Dickinson noted that some national response agencies do have standing MOUs/MOAs, so they can be done, although difficult. Mr. Fugate commented that the NWS provides full time staff to FEMA, and FEMA provides staff to the NHC, so there is precedent in standing employee sharing. Dr. Elliott noted that some information can only flow in one direction due to national security or proprietary information.

#### **2:00-2:15: Other Key Recommendations (Dr. Seth Jonas, Lockheed, SWAG Member)**

Dr. Jonas discussed other key recommendations that did not fit under specific sessions previously discussed. The report will have more information on each of these topics.

R.22.1 Develop a national security annex or policy on space weather; understanding the needs and building out the national security enterprise

R.23.1 Improve public awareness, education, and engagement regarding space weather application effects; encouraging further enhancement of outreach efforts

Enhancing global engagement

R.24.1 Foster and lead a global space weather enterprise

R.24.2 Promote Five-Eyes space weather collaborations (Canada, UK, US, Australia, NZ)

R.24.3 Formalize bi-lateral or multilateral agreements to support coordinated messaging, mutual resilience, and to further the global space weather enterprise

R.24.4 Increase the improve coordination between domestic and international government and non-government stakeholders

R.24.5 Participate in and leverage the international standards development relevant to space environment and space weather

Critical need for thermospheric density specification to aid operational systems

R.25.1 Support coordinated applied research for the thermosphere (between 100-600 km altitude) which is critical for space traffic coordination

R.25.2 Support coordinated R2O2R workshops and testbed activities for space traffic coordination

R.25.3 Support and encourage new processes for the incorporation of data and observations to characterize the thermosphere (between 100-600 km altitude) environment



Dr. Knipp commented that there is some uncertainty if the 600 km should be considered the upper limit. Dr. Elliott mentioned that there is aurora around 800 km and suggests it be increased to 850 km. Dr. Tobiska agreed that increasing the upper limit is a great point with Iridium just above 800 km. Dr. Bishop commented that looking at the equations, solar radiation pressure becomes increasingly important above 500 km. The thermosphere density is the driver for the unknowns above 600 km. Dr. Tobiska suggested we could redefine the range since it's variable. Dr. Bishop suggested that we just note the bottom range and say 100 km and above.

Dr. Tobiska noted that if there are roles that agencies can play in sharing education efforts, that should be promoted.

Dr. Dickinson discussed the priority recommendations that she briefed to SWORM. The SWAG selected the top 11 recommendations (order in which they appear in the report). OMB asked for prioritization.

1. Fund the Federal Space Weather Enterprise (R.1.1.)
2. Create and fund an applied research program office for space weather within NOAA to coordinate, facilitate, promote, and transition applied research across the national space weather enterprise (R.2.1.)
3. Ensure OSTP staffing, prioritization, and White House led coordination of the national space weather enterprise (R.3.1. And more)
4. Protect space weather sensors from spectrum interference. (R.5.1.)
5. Provide long-term support for operational ground-based sensors and networks (R.6.2.)
6. Support and fund additional space weather data and services beyond near-Earth (R.9.3.)
7. Fund NASA missions that impact foundational space weather research (R.10.1.)
8. Coordinate benchmark development or improvement with industry. (R.17.1.)
9. Quantify the societal benefits for addressing risk from space weather by performing national-level and industry-wide economic assessments and integrate space weather in the context of broader national risk. (R.21.1.) and (R.4.1.)
10. Foster and lead a global space weather enterprise (R.29.1-5.)
11. Support coordinated applied research within the thermosphere (between 100-600 km altitude) which is critical for space traffic coordination. (R.30.1-3.)

SWAG members agreed to these top priority recommendations.

Dr. Dickinson then opened the floor to SWORM member comments. Mr. Bill Murtagh (SWORM) commented that this report is great and ensures that we have whole of community input into the recommendations. R.6.3. Needs assessment of what is actually needed first...how many? Where? We can't blindly move forward. Dr. Gannon responded that Mr. Murtagh has a really good point. The prioritization work may have already been done in white paper and more needs to be investigated. Dr. Knipp suggested that we use modeling to help decide where and how many observations are needed. SWAG will ensure this wording is in report. Dr. Duncan said this is also addressed in the system architecture section as well but may need to be applied elsewhere. Dr. Gannon emphasized that this all still relies on funding. Dr. Bishop commented that this prioritization needs to be an ongoing process.

Mr. Murtagh commented regarding chapter 25 recommendations, the term prediction should be included as these processes are improved. Dr. Knipp suggested putting the wording into R.25.3.

#### **2:15-2:20: Public Comment**

No verbal public comments. Thomas Berger submitted the comment via webinar registration, "Consider alternative mechanisms for NOAA to engage commercial providers with space weather applications - SBIR is not working"

#### **2:20-2:55: Committee Discussion**

The committee wrapped up discussions on each finding and recommendation and moved to vote on the Report: Space Weather Advisory Group Recommendations and Priority Actions to Improve the National Space Weather Enterprise. Dr. Jonas added that a national risk register is also something that is very important and needs to be done to help prioritize the recommendations. Dr. Tobiska asked what a risk register means. Dr. Jonas explained that it's basically a matrix that ranks various hazards, their likelihood and potential costs/consequences.

Dr. Bishop moved, Dr. Ho seconded, to vote on the report with minor edits discussed and all committee members present via gotowebinar voted in support. Two members, Mr. Mark Olson and Mr. Mike Stills voted in favor of the report via email. The report is approved with 100% support from the SWAG members.

#### **2:55-3:00: Closing Remarks (Dr. Tamara Dickinson, Science Matters Consulting and Chair, SWAG)**

Dr. Dickinson provided closing remarks and highlighted the next SWAG meeting which will take place at the Space Weather Workshop in Boulder, CO on Monday, April 17, 2023. The meeting will focus on focus group training with the recommendations report expected to roll out the following day. Dr. Dickinson went over the details for SWAG participation at the Space Weather Workshop in April 2023. Dr. Dickinson thanked the SWAG members for their hard work and being an incredible team.

#### **3:00: Adjourn**

Dr. Meehan adjourned the meeting at 3:00pm.