

Space Weather Advisory Group (SWAG)

Public Meeting

Via Webinar

Meeting Minutes

Tuesday, March 26, 2024

10:00 AM – 5:00 PM

Meeting Attendees

Committee

Nongovernmental End User Representatives

Dr. Tamara Dickinson, Committee Chair, Science Matters Consulting

Mr. Mark Olson, North American Electric Reliability Corporation

Mr. Michael Stills, United Airlines (retired)

Mr. Craig Fugate, Bent Ear Solutions

Dr. Rebecca Bishop, Aerospace Corp.

Commercial Sector Representatives

Dr. Jennifer Gannon, Computational Physics, Inc.

Dr. Seth Jonas, Lockheed Martin

Dr. Conrad Lautenbacher, GeoOptics, Inc. (not in attendance)

Dr. W. Kent Tobiska, Space Environment Technologies

Dr. Nicole Duncan, BAE Systems, Inc.

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

Ms. Amy Macpherson, Acting National Space Weather Program Manager, National Weather Service

Also Present

Dr. Jennifer Meehan, Assistant Director for Space Policy, OSTP

Dr. Mangala Sharma, NSF

Dr. James Spann, NASA

Meeting Minutes

10:00-10:05: Welcome (Amy Macpherson, SWAG DFO, Acting Space Weather Program Manager, NWS)

Ms. Macpherson welcomed attendees and viewers to the seventh Space Weather Advisory Group (SWAG) meeting. This meeting will focus on the results of the user-needs survey findings and recommendations, as directed by Section 60601 of the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act.

Ms. Macpherson reminded attendees that the PROSWIFT Act directed the National Oceanic and Atmospheric Administration (NOAA) to establish the SWAG to provide advice to the White House Space Weather Operations Research and Mitigation (SWORM) Subcommittee. SWAG is comprised of 15 non-governmental representatives who were appointed in October 2021 with the charge to provide stakeholder input from the academic community, the commercial space weather sector, and space weather end-users to inform the interests and work of the SWORM.

Ms. Macpherson thanked the SWAG Chair, Dr. Tamara Dickinson, for her leadership and the Advisory Group members for their hard work leading up to this meeting, and led the SWAG members in a round of introductions.

10:05-10:15: Opening Remarks, Recap of Meetings 5 and 6, and Progress Since (Dr. Tamara Dickinson, Science Matters Consulting, and Chair, SWAG)

Dr. Dickinson also thanked the SWAG members for their efforts since the Advisory Group's last public meeting in April 2023. Meeting 5 in March 2022 focused on reviewing and approving the SWAG's first report, titled *Findings and Recommendations to Successfully Implement PROSWIFT and Transform the National Space Weather Enterprise*. Meeting 6 was held during the 2023 Space Weather Workshop and included an update on the user-needs survey and a series of user-needs focus groups across three topic areas: human space flight, research, and space traffic management/coordination. Following last year's meetings, Dr. Dickinson and other SWAG members have participated in a number of briefings and presentations on the SWAG's first report to stakeholders and at space weather enterprise-related events and gatherings. Since last June, the SWAG has been fully focused on the user-needs survey. The SWAG has completed focus groups for all sectors covered by the survey, with the exception of the Global Navigation Satellite System (GNSS), which is on a separate timeline than the other sectors. Recent months have been devoted to drafting the formal user-needs survey report.

Dr. Dickinson reviewed the agenda for Meeting 7, which is largely devoted to reviewing and approving the user-needs survey report findings and recommendations.

10:15-10:20: Update from the SWORM (Dr. Jennifer "Jinni" Meehan, Assistant Director for Space Policy, White House Office of Science and Technology Policy (OSTP), SWORM Co-Chair)

Dr. Meehan spoke about her excitement to return to the SWAG, for whom she previously served as DFO, in her new position at OSTP and SWORM Co-Chair. She thanked the SWAG for the findings and recommendations provided in their first report. The SWORM tasked the SWAG with preparing that report as part of its efforts to rewrite the implementation plan for the National Space Weather Strategy and Action Plan. The SWORM incorporated the findings of the SWAG's report into the rewritten implementation plan, which was presented to the National Space Council at its December 2023 meeting. The SWORM is currently working on developing the

deliverables and timelines for the action plan. It is looking forward to the SWAG's user-needs survey of space weather products, which is the primary purpose for the creation of the SWAG. Dr. Meehan noted that the SWORM has begun working with NOAA to revamp the Space Weather Scales and that SWAG's report will be vital in the overall effort to provide usable and actionable updates to space weather-related products.

10:20-10:30: Status of User-Needs Survey (Dr. Tamara Dickinson, Science Matters Consulting, and Chair, SWAG)

Dr. Dickinson reviewed the purpose and objectives of the user-needs survey under the PROSWIFT Act, which include assessing the adequacy of the federal government's goals for lead time, accuracy, and data quality for space weather observations and forecasting, identifying data collection opportunities to address the needs of space weather product users, identifying new technology and research opportunities, and identifying methods and technology to improve space weather event preparedness, among other requirements. Dr. Dickinson reviewed the timeline of the SWAG's work on the user-needs survey dating back to 2021, including activities to conform to the requirements of the Paperwork Reduction Act, which were completed last June. For 2023-2024, the SWAG focused on the following survey sectors: electric power grid, space traffic management/coordination (STM/C), emergency management, aviation, human space flight, research, and GNSS. Dr. Dickinson noted that the STM/C, human space flight, and research sectors had not been focus areas of past survey efforts. She reviewed the survey process, which primarily consisted of anonymized focus groups. The focus groups were asked sector-specific and general questions on topics such as current uses of observations and forecasts and future needs, technologies and components currently affected by space weather, current risk reduction and resilience activities and future needs, new and/or potential future data sources, and next-generation technologies, research instrumentation, and models.

10:30-11:50: Discussion and Approval of User-Needs Survey Report Findings and Recommendations

Dr. Dickinson thanked the SWAG members and staff for their hard work and support that led up to this report. Today's meeting will focus on the discussion and approval of the report's findings and recommendations, not the report text itself. Dr. Dickinson hopes to present on the report at the upcoming Space Weather Workshop on April 16, pending approval by the SWAG today. The full release of the final report is scheduled for the summer of 2024. A follow-up SWAG meeting is scheduled for April 12 to discuss any unfinished recommendations and/or revisions that might be suggested during today's conversations and to prepare for the workshop. If needed, small revisions can be made to the findings and recommendations prior to final approval of the complete report. Dr. Dickinson explained that findings and recommendations were mostly driven by the users themselves via comments received in the focus groups; however, as subject matter experts themselves, SWAG members also provided additional findings and recommendations for topics that were not raised during the focus groups that they believe are important. These will be identified as SWAG Findings and Recommendations and will be found in separate sections at the end of the report chapters. The only other input the SWAG provided on the main findings and recommendations was to suggest specific agencies to address the needs in question.

Electric Power Sector

Mark Olson provided background on the focus group process and scope for the electric power sector, which utilized the North American Electric Reliability Corporation (NERC) mailing list for

outreach. Mr. Olson noted that the North American electric power industry has a relatively mature existing framework for addressing risks of extreme space weather events, but users identified a number of ongoing needs to bolster the framework and help the industry perform mitigation activities, for example, around data collection, model validation, and making space weather forecasts more actionable. Of the four findings for this sector, Dr. Olson highlighted Finding 2.1, focused on model validation, as the highest priority for the users. Finding 2.2 is about making space weather alerts more actionable for industry by increasing data sharing and access to data, among other recommendations. Finding 2.3 focuses on improving industry's tools for performing geomagnetic disturbance (GMD) vulnerability assessments, particularly for addressing harmonic currents. Finding 2.4 calls for increased collaboration between the government and industry to continue to improve risk mitigation efforts.

- **Finding 2.1.** Validation of geomagnetically induced current (GIC) models and vulnerability assessments using GIC and magnetic field measurements are a key priority to advance mitigation of the impacts from GIC.
 - **Recommendation 2.1.1.** NOAA, in collaboration with the U.S. Geological Survey (USGS), should support one or more existing magnetometer arrays and assess priorities for new installations to provide increased public access to geomagnetic field data with adequate coverage, prioritizing areas of higher hazard, to support GIC model validation studies.
 - **Recommendation 2.1.2.** NOAA should collaborate with the Department of Energy (DOE) and power industry software providers to integrate geo-electric field maps and estimates into standard power industry software used for GIC studies and GMD vulnerability assessments.
 - **Recommendation 2.1.3.** NOAA should invest in infrastructure to ingest magnetic field data from privately-owned sensors into operational geo-electric field models to support industry need for GIC model validation studies.
- **Finding 2.2.** The power industry finds existing space weather alerts and warnings to be useful for triggering preparatory actions prior to onset of a GMD event.
 - **Recommendation 2.2.1.** DOE and industry should explore opportunities for developing a new process for direct sharing of real-time GIC data for situational awareness between operators through open access data models and cooperative agreements.
 - **Recommendation 2.2.2.** NOAA should continue to validate and evolve predictive models of the geo-electric field to improve forecasting capabilities and alert lead times.
 - **Recommendation 2.2.3.** NOAA should support the development of regional and local alerts through private sector partnerships.
 - **Recommendation 2.2.4.** NOAA, in collaboration with the power industry, should identify and implement ways to minimize alert latencies, for example, through the use of automated tools.
- **Finding 2.3.** Harmonic studies are an important component of assessing GIC risk. Reliability standard requirements in North America specify that system planners must evaluate harmonic impacts on the transmission system and equipment in their GMD vulnerability assessments.
 - **Recommendation 2.3.1.** DOE should lead a collaborative effort with the power industry to develop capabilities, guidance, and tools for incorporating

GIC-related harmonics in GMD vulnerability assessments and promote widespread adoption and use through standard system planning tools and best practices.

- **Finding 2.4.** Effective GIC mitigation is an interdisciplinary, cross-sector, and community-wide effort, requiring increased collaboration between DOE, the National Labs, and power industry.
 - **Recommendation 2.4.1.** DOE, the National Labs, and power industry should collaborate to update vulnerability assessment tools and capabilities.
 - **Recommendation 2.4.2.** NOAA and USGS, in collaboration with the space weather commercial sector, should provide expanded training opportunities for the power industry on current capabilities for warnings, alerts, and geo-electric field estimates, including those from the commercial sector.
 - **Recommendation 2.4.3.** Department of Homeland Security (DHS) and DOE should solicit sector representatives to participate with other infrastructure sectors and emergency managers to understand and mitigate risks from interdependencies.

Discussion

Bill Murtagh, NOAA Space Weather Prediction Center (SWPC), wondered whether Recommendations 2.1.1 and 2.1.3 were intended to be limited to supporting validation studies. Mr. Olson said industry would benefit from additional planning tools and said Recommendation 2.2.2 was intended to speak more to operational matters. He suggested that 2.2.2 could be revised to mention integration predictive models into real-time display tools or, if necessary, draft an additional recommendation. Mr. Murtagh clarified that his point is that any additional magnetometer coverage will have benefits beyond improving validation models, such as improving real-time geo-electric field products. In response to another question from Mr. Murtagh on Recommendation 2.2.1, Mr. Olson said that the recommendation is geared more towards expanding real-time data sharing for operators on the ground.

The SWAG voted to approve the Electric Power Sector findings and recommendations.

Emergency Management Sector

Craig Fugate began his presentation by defining the emergency management (EM) sector for purposes of the user-needs survey, which includes the Federal Emergency Management Agency (FEMA) and other federal agencies, state, local, and tribal entities, as well as private sector organizations that play important roles in disaster response. The EM user-needs survey primarily focused on the impacts of space weather events on critical infrastructure. The EM Sector team worked with the National Emergency Management Association, which represents the states and territories, and the International Association of Emergency Managers, which represents local-level EM agencies, to solicit survey respondents. Generally speaking, the survey found improved awareness about space weather impacts from past surveys, but there remains a lack of knowledge about those impacts. Unlike other sectors' surveys, the EM Sector prefaced the survey by providing participants an extreme space weather event scenario before asking the predetermined questions.

- **Finding 6.1.** There is not consistent or sufficiently broad awareness of space weather and its effect across the EM community.

- **Recommendation 6.1.1.** FEMA's Preparing the Nation for Space Weather Events Independent Study Course (IS-0066) should be incorporated into EM required training and education.
- **Recommendation 6.1.2.** Space weather is an event of national security and national economy that has national significance. Therefore, Congress or the Office of Management and Budget (OMB) should considering requiring IS-0066 training to receive EM grants.
- **Recommendation 6.1.3.** FEMA, in collaboration with SWPC, should develop tabletop exercise packages for state, local, and tribal governments. Exercises should address impacts of space weather events.
- **Recommendation 6.1.4.** FEMA, in collaboration with the National Security Council staff, should incorporate space weather into the FEMA National Exercise Program schedule.
- **Finding 6.2.** Emergency managers need more information on the impacts of space weather, including cascading impacts, across the broad set of national critical functions and/or infrastructure services.
 - **Recommendation 6.2.1.** NOAA should develop forecasts that include the impacts of space weather events on critical infrastructure similar to what they are doing for terrestrial weather events.
 - **Recommendation 6.2.2.** NOAA, in collaboration with the commercial sector, should produce visualization tools similar to the USGS/NOAA near-real time geo-electric field mapping product.
- **Finding 6.3.** Emergency managers need space weather forecasts linked to regional space weather effects, including infrastructure, system, and service dependencies.
 - **Recommendation 6.3.1.** NOAA and the commercial sector should cooperate to develop regionalized products for EM.
 - **Recommendation 6.3.2.** NOAA, in collaboration with the commercial sector, should develop more regionalized forecasts with impact- and geographic-specific space weather information. NOAA may need to involve social science experts to assist in determining what data, models, and research they need to implement this recommendation.
- **Finding 6.4.** Emergency managers need to be able to better understand what they need to do during the response phase of a space weather event.
 - **Recommendation 6.4.1.** FEMA, in collaboration with NOAA SWPC, should work with state, local, and tribal emergency managers to evolve EM toolkits to address the impacts of space weather within their community, including coordination of EM functions with infrastructure service providers across their region, and planning and exercising for space weather response and recovery.

Discussion

Dr. Dickinson asked Mr. Fugate to clarify what is meant by the sentence "space weather is an event of national security and national economy that has national significance" in Recommendation 6.1.2. Mr. Fugate said that was meant to convey that the EM sector has to be prepared for low probability, high consequence events that, for example, lead to the failure of an entire regional grid for days or weeks and what the infrastructure impacts of such an event would be on societal pillars like healthcare, public safety, etc. Training requirements have to come with federal support and prompting or it will be difficult to convince state and local

agencies to conduct the training without such support. Dr. Dickinson said the recommendation might need to be rephrased to capture the full intention as described by Mr. Fugate. Mr. Fugate proposed revising the first sentence to be more succinct and simply read "Space weather is an event of national significance."

Mr. Murtagh discussed with Mr. Fugate the challenges presented by the existence of EM "super-users" who are particularly adept or up-to-date on space weather topics alongside other EM agencies or leaders who might be completely unaware of space weather impacts. Mr. Murtagh thought the tabletop exercises called for in Recommendation 6.1.3 would be helpful in this regard, but asked whether some kind of requirement to participate was needed. Mr. Fugate said the users expressed aversion to mandates that do not come directly from the federal Executive Branch. Until these kinds of activities can be incorporated into the FEMA program and supported by funding, general education about space weather impacts and development of training tools will be an important priority.

The SWAG voted to approve the Emergency Management Sector findings and recommendations, with minor edits.

GNSS Sector

Dr. Rebecca Bishop provided an update on the GNSS Sector's activities. The GNSS team is still in the early stages of conducting its user-needs survey and does not have findings or recommendations to present today. Dr. Bishop noted that the GNSS Sector covers a wide variety of types of users and technologies that rely on integrated GNSS data and systems. In order to make this large array of users more manageable for surveying, the sector has been divided into two focus areas, precise timing and position/navigation, under which a number of "community groups" have been identified. Dr. Bishop noted that they are excluding groups already covered by other SWAG sector surveys, such as aviation and the electric industry. If deemed necessary, a GNSS-specific survey for those excluded groups can be conducted at a later date. Dr. Bishop said the survey attempts to address two fundamental questions: 1) What is the threshold of GNSS outage or degradation that will adversely affect an individual community/application? 2) Can space weather events exceed that threshold?

The survey will be conducted over two years via a combination of small focus groups and web-based surveys. Dr. Bishop said that the goal of the web survey is to get a broad assessment of levels of knowledge about space weather impacts on specific communities and what the impacts of a GNSS outage on the communities would be. In the first year, the survey effort will focus on the following community groups: communication networks, manufacturing, distribution, land usage, and public safety and services. The online survey opened in November 2023 and has received 44 responses so far. Dr. Bishop said that the preliminary impression from these responses is there is a lack of understanding among end-users about GPS technology embedded in their applications and basic space weather concepts. In the coming months the team will start to convene panel survey sessions with at least two members of each community group. The results of the web survey suggest technology developers may need to be included.

Dr. Delores Knipp asked if GNSS vulnerabilities in the context of space traffic management will be a specific topic of discussion. Dr. Bishop said the GNSS Sector will work with the other sectors after the completion of the report to see if they feel GNSS implications were sufficiently covered in their respective sectors. If more discussion of this topic is needed, then the GNSS team can incorporate more sector-specific questions in its Year 2 activities. Dr. Bishop asked anyone interested in participating in the GNSS Sector survey activities as a respondent to reach out to her and the SWAG.

Space Traffic Management/Coordination (STM/C) Sector

Dr. Dickinson invited Dr. Knipp to provide an introduction to her sector's findings and recommendations prior to the scheduled lunch break. Dr. Knipp opened her introduction by noting that there are now over 8,000 low Earth orbit (LEO) satellites, a significant increase in recent years that Dr. Knipp described as a sea change. Given the large size of the sector, federal/Department of Defense (DOD) users and academia were not included in the survey but might be candidates for a follow-up survey at a later date. The sector team coordinated its activities to coincide with the 2023 NOAA Satellite Testbed Exercise and divided the sector into four sub-sectors: satellite owner/operators, tracking and maneuvering services, data-gathering platforms, and data service providers and product developers. Dr. Knipp noted that there was no previous survey for this sector and the findings track with the comments of the 2023 SWAG report regarding the need for baseline models and data streams to improve coordination. The consensus highest priority concern was the need for neutral density (ND) information.

11:50-12:30: Lunch Break

12:30-2:45: Discussion and Approval of User-Needs Survey Report Findings and Recommendations

Space Traffic Management/Coordination (STM/C) Sector (Continued)

Dr. Knipp noted that the STM/C Sector grouped its findings and recommendations into four categories: product acquisition and availability, development and validation, dissemination and other STM/C concerns, and SWAG findings and recommendations.

Product Acquisition and Availability

- **Finding 5.1.** A framework is needed to acquire, validate, and share inferred neutral density (ND) values.
 - **Recommendation 5.1.1.** NOAA, working with the commercial sector, should invest in data collection and information-sharing that informs estimates of ND.
 - **Recommendation 5.1.2.** NOAA Space Weather Operations (SWO) and SWPC, working with the broader Space Weather Enterprise, should develop new observations, paths for acquiring satellite constellation ND information, and new forecasting capabilities for lower thermosphere (very low Earth orbit to LEO).
- **Finding 5.2.** Environmental input parameters need to be maintained and archived for ND models.
 - **Recommendation 5.2.1.** The National Centers for Environmental Information (NCEI) and SWPC should expand and maintain archives of indices and proxies.
 - **Recommendation 5.2.2.** NASA and NOAA should improve cross-agency investment for transitioning measurements to operational products.
- **Finding 5.3.** Users need availability of quality-defined ND model output and product information.
 - **Recommendation 5.3.1.** NCEI and SWPC should work with users via focus groups, testbed exercises, and workshops to determine format and documentation requirements for ND information.
 - **Recommendation 5.3.2.** SWPC, in collaboration with provider and user communities, should include and document uncertainties associated with all ND-related products.

- **Finding 5.4.** Users need accessible long-term ND databases for model validation.
 - **Recommendation 5.4.1.** NCEI and SWPC should determine the cause of latency in data and model output availability and implement a plan to address it.
 - **Recommendation 5.4.2.** NOAA, NCEI, and SWPC should develop and implement a sustainable plan for archiving ND model output in a database that is stable, accessible, interoperable, and machine-readable with modern change and outage notification protocols.

Development and Validation

- **Finding 5.5.** Users need near-term ND forecast improvements and model development.
 - **Recommendation 5.5.1.** SWPC should extend and continue its engagement with the user community to determine developmental needs for forecast cadence and resolution and latitude requirements for ND forecasting, thresholds for alerts and warnings, and need for neutral winds.
 - **Recommendation 5.5.2.** As part of the R2O2R process, NOAA SWO, SWPC, NASA, National Science Foundation (NSF), and DOD should work with satellite owners/operators in all altitude regimes to facilitate data acquisition and sharing for improving ND nowcasting and forecasting.
 - **Recommendation 5.5.3.** SWPC and academic and commercial model developers should strive for two-way coupling in their models.
 - **Recommendation 5.5.4.** NASA and NSF, in collaboration with industry, should invest in science machine learning underpinnings of reduced order models (ROMs) to support on-orbit LEO constellation operations.
- **Finding 5.6.** Users need long-term ND forecast improvements and model development for conjunction assessments.
 - **Recommendation 5.6.1.** NASA, NOAA, NSF, and DOD should support R&D for ND forecasts extending from 3 to 7 days to meet the needs of the STM/C community, in particular for service providers such as NOAA's Office of Space Commerce (OSC) Traffic Coordination System for Space (TraCSS) and commercial product developers.
 - **Recommendation 5.6.2.** NASA, NOAA, NSF, and DOD should invest in observational capabilities. Develop and deploy priority operational instrumentation that will enable forecasts for multi-day epochs. International collaboration should be supported.
 - **Recommendation 5.6.3.** NOAA and the research community should develop an ensemble modeling capability that parallels ensemble capabilities in terrestrial weather forecasting. Users generally agreed that ensemble ND modeling is an important long-term goal.
- **Finding 5.7.** Users need long-term solar cycle model development for forecast improvements.
 - **Recommendation 5.7.1.** NASA and NSF should fund research in solar cycle forecasting that supports long-term mission planning.
- **Finding 5.8.** Users need regularly scheduled ND model validation as a key component of R2O.
 - **Recommendation 5.8.1.** NOAA, in collaboration with SWPC, should publish systematic validations of Whole Atmosphere Model-Ionosphere Plasmasphere Electrodynamics (WAM-IPE) as part of a continuing R2O process.

- **Recommendation 5.8.1.** Relevant SWORM agencies should include validation protocols in future federally-funded ND modeling intended for R2O.

Dissemination and Other STM/C Concerns

- **Finding 5.9.** Users need clarity about notification of ND forecast updates, especially those related to abrupt changes.
 - **Recommendation 5.9.1.** SWPC should expand dissemination of ND alerts and forecast descriptions.
- **Finding 5.10.** Participants want clarity about how space weather information is being used in OSC TraCSS.
 - **Recommendation 5.10.1.** NOAA and OSC should clarify to the broader STM/C community how actual and forecast changes in ND will feed into conjunction risk assessment algorithms.
 - **Recommendation 5.10.2.** When TraCSS becomes operational in late 2024, OSC, in collaboration with NOAA SWO and SWPC, should evaluate and quantify the influence of space weather ND information on the conjunction risk assessments.
- **Finding 5.11.** Beyond ND information, satellite constellation operators and product developers need data and information about the LEO charging and radiation environment, as well as the radio communication environment, for current operations and anomaly resolution.
 - **Recommendation 5.11.1.** The SWORM should coordinate with users across the National Space Weather Enterprise and invest in information-sharing that supports real-time charging and radiation environment characterization and production across the broad LEO regime.
 - **Recommendation 5.11.2.** SWPC, in collaboration with STM/C industry, academia, and commercial space weather organizations, should establish regular testbed training exercises, including simulations, focused on STM/C.
- **Finding 5.12.** The user community needs reliable information on GNSS signal disruption associated with space weather.
 - **Recommendation 5.12.1.** SWPC should determine if products from the 2020 International Civil Aviation Organization (ICAO) aviation space weather advisory system are sufficient to meet STM/C needs.
 - **Recommendation 5.12.2.** Relevant SWORM agencies should coordinate with users across the National Space Weather Enterprise to invest in information-sharing that supports real-time radio communications characterization and prediction across the VLEO to LEO regime.
 - **Recommendation 5.12.3.** SWAG should continue to investigate GNSS reliability needs in the upcoming GNSS User Needs Survey and Satellite Operations User Needs Survey.

SWAG Recommendations

- **Finding SWAG 5.1.** There is a need for implementation of a near-term ND forecast strategy.
 - **Recommendation SWAG 5.1.1.** SWORM should update its 2024 implementation plan to provide a path forward for observing, modeling, and forecasting, thermospheric quantities for STM/C.
- **Finding SWAG 5.2.** There is an immediate need for progress and consistency in validation of data, models, and associated uncertainties.

- **Recommendation SWAG 5.2.1.** SWPC should expand their feedback to data providers on the suitability of their data for SWPC use in nowcasting or forecasting through ongoing engagement such as testbeds and focus groups.
- **Recommendation SWAG 5.2.2.** When the SWPC testbed becomes fully operational, NOAA should ensure that sufficient resources and means are available to use the testbed for validation of data sets and models.
- **Recommendation SWAG 5.2.3.** SWPC and SWORM should coordinate with the Space Weather Roundtable to convene a meeting on needs and progress in thermosphere and ionosphere data and model validation with the intent to gain more understanding of the current state of the art.
- **Finding SWAG 5.3.** SWPC's WAM-IPE should be two-way coupled.
 - **Recommendation SWAG 5.3.1.** SWPC should ensure that the WAM-IPE becomes two-way coupled in order to achieve its full potential as a forecast model that assimilates thermospheric data in support of STM/C needs.
- **Finding SWAG 5.4.** There is a long-term interest in ensemble modeling capability that parallels ensemble capabilities in terrestrial weather forecasting.
 - **Recommendation SWAG 5.4.1.** Relevant SWORM agencies should develop a framework to support ensemble model development.

Discussion

Dr. James Spann, NOAA Office of Space Weather Operations, asked if the users talked about data assimilation capabilities. Dr. Knipp said data assimilation was not raised explicitly, but there was an implicit awareness that the ROMs would work best as data assimilators. SWAG may need to acknowledge separately that data assimilation is considered to be the hallmark of mature forecasting models. Dr. Spann said it would be beneficial to include a statement to that effect in the recommendations.

Dr. Dickinson and Dr. Knipp discussed Recommendation 5.6.2, which Dr. Knipp said was intended to specifically address multi-day forecasts. Dr. Dickinson said the recommendation might need to be reworded or fleshed out to make that clearer. Dr. Nicole Duncan suggested that the recommendation could be revised to read "NASA, NOAA, NSF, and DOD should develop and deploy priority operational instrumentation that will enable forecasts for multi-day epochs." Dr. Kent Tobiska commented that predicting solar storms is the key to longer-term forecasts and asked if a statement to that effect would be appropriate as part of this recommendation. Dr. Knipp agreed that it would and said she would work offline to insert the proper language.

The SWAG voted to approve the STM/C Sector findings and recommendations, with minor edits.

Aviation Sector

Michael Stills delivered the presentation.

- **Finding 3.1.** There is a lack of framework, policies, education, and training across the aviation industry.
 - **Recommendation 3.1.1.** DOT, FAA, NIST, and NOAA should coordinate with agencies or entities, including ICAO, ISO, and WMO, to create industry-wide best practices, guidelines, or standards.
 - **Recommendation 3.1.2.** The FAA should develop appropriate policies and regulations that enable the aviation industry to respond safely and effectively to space weather conditions.

- **Recommendation 3.1.3.** SWORM should coordinate with suitable entities, including aviation professional associations, colleges and universities, and commercial organizations, to develop appropriate curricula on the causes of, informational sources for, risks to aviation, and mitigation instructions about space weather and its effects on aviation.
- **Recommendation 3.1.4.** SWPC, in collaboration with aviation industry, academia, and commercial space weather organizations, should establish regular testbed exercises, including simulations, focused on aviation.
- **Finding 3.2.** There is a lack of radiation measurements, reporting, limits, education, mitigation, and standardization across the aviation industry.
 - **Recommendation 3.2.1.** The Department of Commerce (DOC) and NOAA, in collaboration with NASA, NSF, and FAA, should conduct or acquire ionizing radiation measurements at all relevant aviation altitudes and make them available for use by the aviation community.
 - **Recommendation 3.2.2.** The FAA, in collaboration with SWPC and NASA, should develop public-facing educational materials that clearly explain the elements of human exposure to radiation when flying at altitudes normally used by commercial and corporate aviation.
 - **Recommendation 3.2.3.** The FAA, NASA, and NOAA in concert with academia should expand their data reporting and data collection mechanisms to the aviation community in order to obtain scientific measurements which can validate existing models such as FAA CARI and NASA NAIRAS.
 - **Recommendation 3.2.4.** The FAA, in collaboration with qualified organizations such as the NCRP and ICRP, should establish practicable limits and regulatory guidance for crew and passenger radiation exposure limits based on scientific measurements and validated modeling
 - **Recommendation 3.2.5.** Relevant SWORM agencies should promulgate internationally recognizable best practices, guidelines, or standards, developed by entities such as ICAO, ISO, and WMO, for radiation exposure procedures for use by the aviation community.
- **Finding 3.3.** There is a lack of navigation measurements, modeling, and standardization across the aviation industry.
 - **Recommendation 3.3.1.** DOT, FAA, and DOD, in collaboration with DOC, should conduct or acquire measured navigational information, including GNSS uncertainties, from the ground to aviation altitudes and make them available for common use by the aviation community.
 - **Recommendation 3.3.2.** The FAA, NASA, and SWPC, in concert with academia and industry, should continue to improve and validate existing ionosphere models, enable new and additional measurements of the ionosphere, and support the development of data-assimilative modeling for the navigation environment.
 - **Recommendation 3.3.3.** Relevant SWORM agencies should promulgate internationally-recognizable best practices, guidelines, or standards—developed by entities such as ICAO, ISO, and WMO—for mitigating navigation interruption hazards for use by aviation operators.
- **Finding 3.4.** There is a lack of communication measurement, modeling, and standardization across the aviation industry.

- **Recommendation 3.4.1.** DHS, the Federal Communications Commission (FCC), the National Telecommunications and Information Administration (NTIA), DOT, and FAA should conduct or acquire measured communication information, including HF propagation and UHF uncertainties, from the ground to aviation altitudes and make them available for common use by the aviation community.
- **Recommendation 3.4.2.** The FAA, NASA, and SWPC, in concert with academia and industry, should continue to improve and validate existing ionosphere models with more measurements, and support the development of data-assimilative modeling for the communication environment.
- **Recommendation 3.4.3.** Relevant SWORM agencies should promulgate internationally recognizable best practices, guidelines, or standards—developed by entities such as ICAO, ISO, and WMO—for mitigating communication interruption hazards for use by aviation operators.
- **Finding 3.5.** Aviation industry needs accurate forecasts with longer lead times (beyond 12 hours).
 - **Recommendation 3.5.1.** NOAA Ocean and Atmospheric Research (OAR), NASA, and NSF should oversee expanded scientific data collection in time and space as well as coordinate expanded fundamental and applied research to develop accurate, operational space weather forecasts beyond 12 hours.
- **Finding 3.6.** There is a lack of threat awareness, protocols, planning tools, and oversight across the aviation industry.
 - **Recommendation 3.6.1.** The FAA, in collaboration with the aviation industry and NOAA, should develop a thorough space weather threat analysis that can become the framework for a Safety Management System (SMS).
 - **Recommendation 3.6.2.** The FAA, in collaboration with the aviation industry, NOAA, and NASA, should develop regulations and policies that address mitigation strategies and solutions to space weather related disruptions.

Discussion

SWAG members proposed and implemented minor edits to the wording of several recommendations to improve clarity and accuracy. In particular, there was some debate about whether DOC or OSC should be the responsible entity for data buys in Recommendation 3.2.1. Dr. Dickinson said SWAG should double-check this against the text of the PROSWIFT Act for the final report.

The SWAG voted to approve the STM/C Sector findings and recommendations, with minor edits.

Human Space Flight Sector

Dr. Tobiska described the sector's process for collecting survey comments and feedback, which took place over separate virtual meeting sessions with governmental representatives and the commercial human space flight community. Dr. Tobiska noted some of the broad themes that emerged, including the need for improved radiation mitigation, increased education, and the paucity of regulation and formal policy guidance related to human space flight and related space weather considerations. Dr. Tobiska noted that the commercial sector argued for the ability to self-regulate, while the agency respondents wanted to see existing guidance strengthened or expanded. The respondents were also interested in observations, forecasting, and risk management, and the data framework needed to support these activities. Dr. Tobiska added that NASA astronauts talked about reaching their career dose limits and not being able to serve on future flights due to radiation models that are based on law rather than actual measurements.

- **Finding 4.1.** Radiation measurements, modeling, and tools must be a priority for commercial human space flight (HSF).
 - **Recommendation 4.1.1.** NASA and NOAA, in collaboration with OSC, DOE, DOD, industry, and academia, should conduct or acquire ionizing radiation measurements, including dose and dose rate changes with high time resolution, and all relevant flight altitudes (suborbital, LEO, deep space, Moon, and Mars).
 - **Recommendation 4.1.2.** NASA and NOAA, in collaboration with OSC, FAA, DOE, DOD, industry, and academia, should continue to improve and validate existing U.S. radiation models.
 - **Recommendation 4.1.3.** OSC, NOAA, NASA, FAA, DOE, and DOD, in collaboration with industry and academia, should fund the development of tools that commercial companies can use to specify the local radiation environment based on their specific systems and locations.
- **Finding 4.2.** There is a lack of lunar and Mars-centric space weather tools.
 - **Recommendation 4.2.1.** NASA and NOAA, in collaboration with NSF, industry, and academia, as well as with advice from the Decadal Survey, should consider acquisition of space weather particles and fields measurements at and near the Moon and Mars, as well as other HSF-relevant locations, and make them available for common use by the HSF community.
 - **Recommendation 4.2.2.** NASA and NOAA, in collaboration with NSF, industry, and academia, should continue to improve and validate existing models of Moon and Mars radiation environments.
 - **Recommendation 4.2.3.** NASA and NOAA, in collaboration with the commercial sector, should support the development of real-time, automated flare location products and CME solar system forecasts.
 - **Recommendation 4.2.4.** NOAA should develop space weather indices for HSF-relevant environments.
- **Finding 4.3.** There is a lack of measurements and models for design.
 - **Recommendation 4.3.1.** The OSC, NOAA, NASA, FAA, DOE, and DOD, in collaboration with industry and academia, should improve accuracy of radiation dose measurements for astronauts and private mission crews through improved monitoring and modeling of dynamic regions such as the South Atlantic Anomaly.
 - **Recommendation 4.3.2.** The OSC, NOAA, NASA, DOE, and DOD should support development of on-board sensor suites of particles and fields detectors in support of both public and private sector missions.
 - **Recommendation 4.3.3.** NOAA, NASA, and NSF should consider the support of existing ground-based neutron monitor networks in its prioritization of ground-based measurements.
 - **Recommendation 4.3.4.** NOAA SWPC, in collaboration with OSC and NASA, should support the collection, validation, and timely distribution of space weather measurements, including those by the commercial sector, and support the development of models in the academic and commercial sectors.
 - **Recommendation 4.3.5.** NOAA, NSF, and NASA should fund the development of models and tools that improve the accuracy of forecasting and predictions for a launch date plus 3 days and for flight readiness reviews at least 2 weeks out.

- **Recommendation 4.3.6.** NOAA, in collaboration with NSF, NASA, industry, and academia, should develop climatology models specific to Mars and lunar environments, to enable long-term planning and mission design.
- **Finding 4.4.** There is a lack of regulatory oversight.
 - **Recommendation 4.4.1.** The SWORM, with inputs from FAA, NASA, OSC, NIOSH, and OSHA, and in collaboration with industry and academia, should improve the language of CFR Part 460 – Human Space Flight Requirements.
 - **Recommendation 4.4.2.** The SWORM should determine an appropriate method for establishing policy and regulatory guidance for limiting crew and passenger radiation exposure.

SWAG Recommendations

- **Finding SWAG 4.1.** There is a need for a gap analysis.
 - **Recommendation SWAG 4.1.1.** NASA should fund a gap analysis study across agencies, academia, and industry to ensure all facets of the human space flight sector are able to identify mitigation strategies and provide actionable solutions for space weather related disruptions.
- **Finding SWAG 4.2.** There is a need for continuing space weather enterprise engagement.
 - **SWAG Recommendation 4.4.2.** The SWORM should create a suitable process across agencies, academia, and industry that ensures all facets of how space weather affects the NSF sector can be utilized to provide fundamental knowledge, quality measurements, validated models, and actionable solutions through user-friendly tools for space weather related disruptions.
- **Finding SWAG 4.3.** There is a lack of micrometeoroid and debris measurements and modeling.
 - **SWAG Recommendation 4.3.1.** NASA and NOAA, in collaboration with OSC, DOE, DOD, industry, and academia, should acquire measurements of micrometeoroids and orbital debris (MMOD) in the millimeter to centimeter size range at LEO flight altitudes and make them available for use by the HSF community.
 - **SWAG Recommendation 4.3.2.** NASA and NOAA, in collaboration with OSC, FAA, DOE, DOD, industry, and academia, should continue to improve and validate existing U.S. MMOD models for LEO that extend in time out to 25 years or two solar cycles.
 - **SWAG Recommendation 4.3.3.** NASA and NOAA, in collaboration with NSF, industry, and academia, should continue to improve and validate existing models of Moon and Mars dust environments.

Discussion

Regarding Recommendation 4.1.1, Dr. Bishop asked if the respondents specified a time resolution that they were seeking. Dr. Tobiska said there were comments about getting down to one second, but the general sense was to get as high a time resolution as possible. Dr. Bishop suggested that the final report be clear about what the end users want and what providers are capable of producing.

Dr. Knipp said that there were comments in the STM/C Sector about the South Atlantic Anomaly in the same vein as Recommendation 4.3.1. Although STM/C did not feel it rose to the level of a recommendation, this might be an overarching SWAG topic to be highlighted in the report. Dr. Knipp also noted that there is new GNSS research looking at MMOD signals.

Dr. Duncan suggested providing more detail in SWAG Finding 4.1 to clarify what kind of gap analysis is needed in the HSF context. She also commented, regarding SWAG Recommendation 4.3.3, that the Moon and Mars dust environments will be affected by increased human activity that will have to be accounted for. Dr. Dickinson said these comments will have to be clear about the relevance for space weather so SWAG does not go beyond its charge as a committee. Dr. Tobiska acknowledged this point, and stated that MMOD of natural and human origin both become modulated by space weather forces. In other words, while these phenomena are not created by weather, they are affected by it. Dr. Seth Jonas said he agreed with these comments and that the SWAG should be clear about this distinction in its report and highlight the connection with STM/C on this topic.

The SWAG voted to approve the STM/C Sector findings and recommendations, with minor edits.

Research Sector

Dr. Dickinson noted that there had been significant restructuring and revising of the Research Sector's recommendations in the days and hours leading up to the meeting, and some might need additional edits before the final report.

Dr. Scott McIntosh delivered the presentation and began by emphasizing the broadness of the sector and the breadth of the survey topics and responses. The findings and recommendations have been grouped into three categories: planning and investment, sensor development, and product acquisition and availability.

Planning and Investment

- **Finding 7.1.** The national space weather enterprise needs an integrated and detailed functional implementation plan that enables appropriate research efforts to support it.
 - **Recommendation 7.1.1.** SWORM should initiate a detailed implementation plan to optimize, prioritize, and sequence actions necessary to advance space weather forecast capability.
- **Finding 7.2.** Focusing on the full R2O and O2R cycle is critical to improving space weather nowcasting, forecasting, and mitigation.
 - **Recommendation 7.2.1.** NOAA, NASA, NSF, and DOD should improve coordination during the selection and development process throughout the complete R2O-O2R cycle.
 - **Recommendation 7.2.2.** NOAA, NASA, NSF, USGS, and DOD should improve the R2O-O2R development process by developing standards and common procedures for testing nowcasting and forecasting capabilities.
- **Finding 7.3.** An Observing System Simulation Experiment (OSSE) framework is required to assess the impacts of future potential observing systems for forecasts and predictions.
 - **Recommendation 7.3.1.** NOAA, NASA, NSF, USGS, and DOD should collaboratively invest in consultation with the research community to develop a framework relying on OSSE analysis for prioritizing space weather observations.
- **Finding 7.4.** The users repeatedly expressed concern regarding the current inadequate investment in key aspects of space weather observational capabilities and infrastructure required for improving space weather forecasting.
 - **Recommendation 7.4.1.** NASA, NOAA, NSF, DOD, and USGS should preserve existing, and develop redundancy for, key long-term historical (multi-decadal) observations.

- **Finding 7.5.** The users highlighted the need for next generation computational resources and data analysis techniques for application to space weather research.
 - **Recommendation 7.5.1.** NASA, NOAA, and NSF should expand investment in and use of new computing architectures and resources.

Sensor Development

- **Finding 7.6.** The survey researchers emphasized the need for improved spatial and temporal observations required to enable research leading to improved space weather forecasting.
 - **Recommendation 7.6.1.** NOAA, NASA, NSF, USGS, and DOD, in collaboration with the commercial sector, should increase space weather observation capability through in-situ sampling instrumentation, ground- and space-based sensors, and associated ground infrastructure in order to increase overall downlink capacity.
 - **Recommendation 7.6.2.** To fill observational gaps, NOAA, NASA, NSF, USGS, and DOD, in collaboration with the commercial sector, should develop, test, and deploy new ground, airborne, and space-based instrument designs that use fewer resources informed by OSSE-backed analysis.
 - **Recommendation 7.6.3.** NASA, NSF, and DOD should work with commercial providers and the research community to develop robust platforms to reduce risk and cost, and prioritize increased reliability, availability, and spatial sampling of space-based systems.

Product Acquisition and Availability

- **Finding 7.7.** The users strongly stated the need for accessible historical and ongoing critical measurements that are integral for improving, verifying, and validating space weather research and forecast capabilities.
 - **Recommendation 7.7.1.** NASA, NOAA, DOD, DOE, the National Labs, and the commercial sector should work together to include 'housekeeping' and metadata as data products for all space-based environmental instrumental datasets.
 - **Recommendation 7.7.2.** NOAA, NASA, NSF, and DOD should archive and maintain existing and future space weather, solar, space physics, and geophysical data.
- **Finding 7.8.** The users stated that many longstanding observations (e.g., F10.7, Kp, magnetograph flux maps, sunspot number) are critical inputs for testing new nowcasting and forecasting capabilities.
 - **Recommendation 7.8.1.** NASA, NOAA, DOD, NSF, USGS, and DOD should adequately support the maintenance, validation, and calibration of existing key space weather ground-based, space-based, and airborne network and sensor data.
 - **Recommendation 7.8.2.** NOAA, NASA, NSF, USGS, and DOD should augment the facilities' infrastructure and instrumentation capabilities to obtain real-time or near real-time observations.

SWAG Recommendations

- **Finding SWAG 7.1.** Non-Keplerian observations are required to improve forecast lead time and accuracy.

- **Recommendation SWAG 7.1.1.** NASA should develop and demonstrate pointing stabilized alternative propulsion methods.
- **Recommendation SWAG 7.1.2.** NASA should develop, demonstrate, and deploy compact small-satellite buses to rapidly explore non-Lagrangian points along the Sun-Earth line, off the Sun-Earth line, and out of the ecliptic plane.
- **Finding SWAG 7.2.** Key observation types are needed for accurate nowcasts and longer-range forecasts and general Sun-Earth system understanding.
 - **SWAG Recommendation 7.2.1.** NASA and NSF should develop ground- and space-based imaging and coronagraphic technologies to characterize the magnetic field of the Sun's corona.
 - **SWAG Recommendation 7.2.2.** NASA and NSF should develop ground- and space-based spectroscopic imaging technologies to characterize the velocities of the Sun's atmosphere.

Discussion

SWAG members suggested explaining in the report footnote what is meant by non-Keplerian observations, or to revise the SWAG Finding 7.1 language to be clearer. SWAG members also suggested edits to Recommendation 7.6.1 to emphasize the importance of downlink capacity, to include collaboration with the commercial sector in Recommendations 7.6.1 and 7.6.2, and to add USGS as a responsible agency in Recommendation 7.4.1.

Dr. Knipp said that Finding 7.3 on the OSSE analysis framework was a candidate for an overarching topic given its STM/C relevance, and Findings 7.6, 7.7, and 7.8 also share some commonalities with Chapter 5. Dr. Tobiska suggested SWAG Finding 7.1 as a potential transformative topic. Dr. Dickinson said the SWAG's April 12 meeting will further flesh out how the committee wants to frame its overarching, transformative, and priorities categories. Dr. Bishop proposed revising Recommendation SWAG 7.1.2 to read "NASA should develop and demonstrate compact small-satellite buses" because any decisions about deployment should be made after prioritization. Dr. Jennifer Gannon suggested the language "NASA should consider developing and demonstrating" as an alternative. Dr. Dickinson said the SWAG should describe in the report how this project differs from activities surrounding the Decadal Survey. Dr. Tamas Gombosi said the SWAG should comment on the limitations of the traditional space weather indices.

Dr. Dickinson proposed that the SWAG hold off on approving the Chapter 7 findings and recommendations until all the proposed changes could be further discussed and fully incorporated into the text.

2:45-3:00: Break

3:00-3:45: Discussion of Report Chapter on Overarching, Priority, and Transformative Issues

The SWAG completed its review of the findings and recommendations ahead of schedule and spent the remainder of the time originally set aside for this activity discussing overarching and transformative topics to highlight in the final report. The overarching themes that were identified by SWAG members included forecast regionalization and impacts, education/training and testbeds (including funding support), expansion of data (including archives, resolution, and accessibility), reducing latency on alerts, uncertainty quantification, public-private partnerships, industry-to-industry data sharing, the need for increased funding to support SWAG

recommendations, automation of information dissemination, and model validation. Dr. Dickinson said that she envisioned a brief discussion in the final report that would describe how these topics cut across multiple sectors and their importance to the overall SWAG mission.

The SWAG next discussed potential priority topics for each sector. These included magnetometer data close to the power system (Power Sector), defining aviation crew members as working in a high-radiation environment (Aviation Sector), ND data (STM/C Sector), automation and data (HSF Sector), data availability and increased coverage (Research Sector), and regionalized forecast impacts (EM Sector). Dr. Tobiska highlighted education as a cross-cutting priority.

SWAG members also identified transformative topics for each sector: non-Keplerian orbits (Research Sector), using proliferated constellations to obtain ND coverage (STM/C Sector), aviation crew working in a high radiation environment (Aviation Sector), developing next-generation ground infrastructure for increased telemetry capacity and new technologies to observe solar wind before it arrives at its destination (Research Sector), understanding the national EM system at each level and developing level-specific messaging and tools (EM Sector), and developing an interdisciplinary workforce (Research Sector). Dr. Bishop noted that there is some overlap between transformative and priority topics and SWAG might need to better define in the report what it means by transformative.

Dr. Dickinson suggested that the SWAG identify some recommendations that can be classified as low-hanging fruit, to complement the more long-term, aspirational transformative topics. Items for this short-term category included making existing data accessible and archived, additional data buys and increased ingestion of commercial and academic instrumentation data, developing R2O2R models and products that are ready to ingest data, and establishing expanded testbed activities.

3:45-4:00: Public Comment

Ms. Macpherson opened the public comment period and read the comments that were received in writing before and during the meeting. Paul Guy from the Federal Energy Regulatory Commission (FERC) expressed interest in GMD impacts on energy infrastructure, especially GIC on transmission lines. Mr. Olson said the Energy Sector recommendations should help address these issues.

Karma Kumlin-Diers, Ramsey County, Minnesota, Emergency Management Department, said emergency managers need actionable information with degrees of confidence for both planning and response. Mr. Fugate said the EM Sector findings and recommendations reflect similar comments received in their survey.

Vincent Ledvina, graduate student at the University of Alaska Fairbanks, suggested that the next SWAG survey include a citizen science and general public sector. Dr. Dickinson said this comment was a good reminder for the SWAG to consider additional sectors for future surveys.

Additional written comments addressed topics such as providing support for grant-writing, benefits and risks of quantum computing, environmental impacts of resource extraction, and public outreach and education. SWAG members clarified that quantum computing exists in only an experimental state and that the commenter might be referring to high performance computing. Dr. McIntosh noted that the Research Sector recommendations include the language "new computing architectures and resources," which was intentionally broad to include future advances and emerging technologies. Another comment asked whether the SWAG considered

recommendations directed towards the National Labs and other federally-funded R&D centers (FFRDCs). Dr. Dickinson noted that some recommendations did refer to the National Labs, but invited SWAG members to use more specific terminology in some locations. Dr. Tobiska suggested including an appendix in the report that details which agencies correspond to which recommendations.

Michael Wiltberger expressed caution about tasking NSF, which is primarily a grant-funding institution, with operational need recommendations. Dr. Dickinson agreed and said SWAG might need to tighten up the language to clarify NSF's role.

4:00-4:26: Update from Space Weather Roundtable (Geoff Crowley and Sara Gibson)

Dr. Dickinson invited the chairs of the National Academies' Space Weather Roundtable to deliver a presentation on their recent activities. Drs. Crowley and Gibson were joined by Dr. Art Charo, Senior Program Officer at the Space Studies Board. The Space Weather Roundtable was formed in response to the PROSWIFT Act and is charged with "facilitating communication and knowledge transfer among Government participants in the SWORM Interagency Working Group, the academic community, and the commercial space weather sector." The Roundtable discusses activities to facilitate advances in space weather forecasting, increase coordination of space weather R2O and O2R, and improve preparedness for space weather events. Dr. Crowley briefly described the structure of the Roundtable and its relationship to the SWAG and Space Weather Council (SWC), which includes overlapping membership. Some of the recent focus areas for the Roundtable have been ground-based observations and space weather benchmarks and R2O-O2R lessons learned. Recent in-person meetings have included conversations on workforce considerations, SWPC Testbed, the cislunar and further radiation environments, improving communication between research and operations, and increased collaboration between DOD and the civil sector to advance the space weather enterprise. Dr. Crowley discussed in greater detail the Roundtable's focus on R2O2R, and addressing the funding and training challenges that arise in the R2O transition and how to accelerate O2R via research prioritization. Commercial providers also have a role to play in improving R2O2R via increased coordination with government entities. The Roundtable's next in-person meeting is scheduled to take place in July.

4:26-4:44: Update from NASA Space Weather Council (Nicole Duncan, SWAG)

Dr. Duncan, SWC Chair and SWAG Member, delivered the update on the SWC's recent activities. The SWC was established by NASA and reports through the Heliophysics Advisory Committee (HPAC). The SWC's purpose is to serve as a community-based forum for soliciting and coordinating community input and providing advice. Dr. Duncan noted that the SWC's purview is limited to NASA-related activities, unlike the interagency approach of the SWAG and the Roundtable. The SWC's 2023 report is available on its website and the report for 2024 is currently with the HPAC for approval. Dr. Duncan described SWC's findings and recommendations across four task areas: advisory group coordination, gap analyses, Artemis and space biology, and cooperation. The SWC believes that NASA's observational and infrastructure gaps are well understood and the agency should conduct gap-filling analyses that account for return on investment. R2O2R has also been a focus area for the SWC across both the space biology and cooperation tasks, to the extent that the SWC plans to separate out R2O2R as a separate task starting at its next meeting.

4:44-4:52: Next Steps and Closing Remarks (Dr. Tamara Dickinson, Science Matters Consulting, and Chair, SWAG)

Dr. Dickinson said SWAG members will continue to work offline revising the findings and recommendations and refining the SWAG report chapters in preparation for its final release. She invited members to suggest ideas for the report's title and cover art.

The SWAG's next public meeting will take place on April 12, when the committee will vote on the revised Research Sector findings and recommendations and prepare for SWAG's session at the 2024 Space Weather Workshop, which will be held Tuesday, April 16, in Boulder, Colorado. The report chapter editing will continue after the workshop, with the goal of officially rolling out the full report this summer.

Dr. Dickinson thanked the SWAG members for their hard work preparing the user-needs survey findings and recommendations in the lead-up to today's meeting.

4:52: Adjourn

Ms. Macpherson thanked Dr. Dickinson for her leadership and seconded the chair's comments thanking SWAG members for the efforts. She reminded them of the dates of the upcoming meeting and the Space Weather Workshop, and adjourned the meeting at 4:52 p.m.