NASA Space Weather Council

February 22-23, 2024

NASA HQ and Teleconference

MEETING MINUTES

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Nicole Duncan, Chair

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Kelly Korreck, Designated Federal Officer

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Thursday, February 22, 2024

Welcome from the Heliophysics Director

[No notes were requested for welcome from the Heliophysics Director.]

Ethics Training

[No notes were requested for the ethics training.]

Welcome from the NASA Space Weather Program Director

Dr. Kelly Korreck welcomed everyone to the meeting of the Space Weather Council (SWC), a subcommittee meeting of the Heliophysics Advisory Committee (HPAC). Dr. Jamie Favors, Director of the Space Weather Program (SWP) welcomed everyone and expressed excitement for the agenda and the opportunity to hear from different people than have been heard from in the past.

Dr. Favors reviewed the agenda and the Centers of Excellence (COE) and addressed questions that had been sent in advance of the meeting. He gave a review of the last few months, including the transitions of Dr. Jim Spann to the National Oceanic and Atmospheric Administration (NOAA) and Dr. Favors to SWP, in October 2023.

Dr. Favors noted that more people will be joining the SWC soon and invited NASA SWP team members to introduce themselves.

- *Dr. James Favors* has been Dr. Spann's deputy for the last 4 to 4.5 years in the SWP. Prior to that he was in the Earth Sciences Division and the Applied Sciences Program and was a meteorologist. His background includes flight projects, human exploration work, and programmatic work for the division.
- *Dr. Genene Fisher* is a program scientist in Heliophysics and will mark her one-year anniversary at NASA in April 2024. She is currently the program official for the Space Weather COE and also works on interagency activities, such as Space Weather Operations, Research, and Mitigation (SWORM).
- *Dr. Esayas Shume* is a program scientist in Heliophysics. His main interest is research and analysis, in situ science, and IDM-related satellite programs.
- *Mr. Brad Williams* has been a program executive in Heliophysics for over two years, leading missions in the flight portfolio and instrument pipeline efforts. He came from the small satellite industry and academia at the research level, also doing flight projects.
- *Dr. Kelly Korreck* is a project scientist for the SWC and the designated federal officer. Her background is in instrumentation and research.
- *Dr. Reiner Friedel* is a civil servant originally from Los Alamos, with a background in radiation belt science. He joined NASA Headquarters (HQ) about 3 years ago and is in charge of the orbital debris program, which has moved over into the SWP.
- *Dr. Ursula Rick* is a program executive in Heliophysics, who just marked one year there and has been at NASA just over 5 years. She came from the policy branch of NASA. For space weather, she works on missions and is currently working on Vigil. She is interested in using applied science to help the Research-to-Operations-to-Research (R2O2R) program and the instrument pipeline.
- *Mr. Walter Twetten* has been with the Heliophysics Division (HPD) for about 4 years and works on operations and strategy in the background.

Dr. Favors said many people at the meeting support the SWP directly and have a lot of institutional knowledge. However, only Dr. Favors is 100% dedicated to the program.

Dr. Fisher presented a chart on the SW COE. She noted that since the last council meeting, they have selected three COE and also made a joint selection with the Department of Commerce for a fourth COE. They've spoken at Human Exploration & Operations and American Meteorological Society meetings. The SW COE kickoff meeting is mid-March 2024 and each center has held individual kickoff meetings.

Dr. Favors presented and reviewed questions from SWC, sent in advance of the meeting. He noted that a question about the SWP's balance between science and applications was more of an HPD question and that Lawrence Friedl, from Earth Science, would likely address it during this meeting.

The Space Weather Grant Challenge and Space Weather Pipeline continue to make progress. Three of the four current instruments are nearing completion and headed to or already in storage and awaiting in-space hosted opportunities. For potential flight opportunities, a review of the Space Weather Agile Platforms for Science (SWAPS) Request for Information (RFI) collected information from commercial space-based platforms interested in hosting science instruments on a purely hosted payload. Specific hosting opportunities have not been identified, yet, but there will be hosted meetings with commercial providers to start strategizing the path forward.

Next, Dr. Favors answered a question about how the SWP is ensuring the proper evaluation of R2O-type instrument and mission proposals under the SWP (and likely Living with a Star Program). He said the division was not ready to speak to this, although they are considering existing models for replication. Also, Dr. Friedl was scheduled to talk about the Early Adopters Program as a model for consideration during this meeting. Brad Williams, replying to a question from Dr. Vourlidas said that, in terms of collaboration with foreign providers, including ESA and others, those conversations are starting and collaborators are open to discussions.

Welcome from the Chair of the Space Weather Council

Dr. Nicole Duncan thanked the committee for their feedback since the last meeting. She thanked the division for hosting the meeting and providing a valuable opportunity for the community to have a voice. She then emphasized an imperative to drive to closure on findings and recommendations during this meeting.

Adoption of the Minutes from the Last Meeting

The meeting minutes from the last meeting were reviewed and approved: Dr. Alexa Halford, motioned to approve and Dr. Piyush Mehta seconded.

Comments from the Heliophysics Advisory Committee (HPAC)

Dr. Chris Englert, co-chair of HPAC, gave a high-level overview of their charge to SWC. He noted that Dr. Paul Cassak, the Chair of HPAC, was not available for this meeting. Dr. Englert also noted that the charge is in the written recommendations and will be in the official meeting minutes, but he wouldn't be able to add information or interpretation, nor could he speak for HPAC, other than communicating the written words.

Dr. Englert presented the five tasks provided to SWC from HPAC. He noted that the fifth task was new and, further, that the wording was intentionally vague to leave it up to reporters what to report. HPAC is also interested in community feedback on this process.

Dr. Duncan thanked Dr. Englert and sought questions.

Dr. Angelos Vourlidas asked for the rationale for adding Task 5 and whether there was a feeling that the program is undersubscribed or that people don't know how to respond to it. Dr. Englert said HPAC is not aware of a particular problem, but because the program is new, it requires the involvement of the operational part, and connecting to potential principal investigators (PIs) requires some development. He also mentioned that it is intentionally worded to solicit community input. For example, a PI may seek insight on the operational side to create more tailored proposals, or the program may discover how to tailor products to be more digestible by the operational community. It is designed to solicit concerns, pitfalls, and roadblocks from the community, so Heliophysics can find mitigations.

This was the first time Dr. Piyush Mehta had heard of the tabletop exercise (TTX) (Task 2) and he was curious about the need for a report. Dr. Englert agreed that many people are not familiar with TTX and the report would help. Dr. Duncan said that the HPAC heard about the TTX at their last meeting and it is in line with the test bed exercise that happened at SWPC last year, which was a simulated scenario to check on pipeline response. She added that it's more akin to the planetary defense exercise that was held. According to Dr. Vourlidas, who was part of the team that developed the TTX, it is more focused on the response side than the science side and will bring up gaps in knowledge and response and issues with inter-agency coordination. A preliminary report will be issued in July and a more extensive one later in 2024.

In response to a question from Dr. Ron Turner, Dr. Vourlidas said there would not be a website because it has to be a semi-secret scenario/exercise. There will be a draft run in March 2024 to set up logistics with different agencies. Dr. Duncan wondered whether it would be worthwhile for the SWC to be briefed on that draft run to understand what the gaps and outcomes were and pass those on to NASA. Dr. Vourlidas agreed and will report, for summer 2024, on the parts that are NASA-related; for example, the timeliness of the observations or completeness of the input that went into the forecasting.

Dr. Alexa Halford said that tabletops are usually for a very specific type of event, with specific end users and that space weather seems too general. She wondered what specific space weather impacts would be looked at and for how long. Dr. Vourlidas underscored that it's a very specific event, and the TTX is not open to the industry but only to the government. Dr. Duncan moved to discuss this in summer 2024 and make recommendations for the next opportunity. Dr. Genene Fisher added that the exercise is one in a series, the first of which is government-only for specific scenarios with exercise experts to understand responses to different sectors, critical infrastructure operators, etc. The experts have agreed upon a specific scenario and people in the room to determine how reporting up to the president would occur. The report will be made public, and the exercise is funded by NASA, NOAA, and the National Science Foundation (NSF). The second TTX, if funded, would include industry and international partners. There was some discussion about under which task the TTX belongs and ultimate agreement was that it is book-kept under Task 2.

Dr. Duncan thanked Dr. Englert for his presentation and introduced Topic 1.

Topic 1: Coordination with Other Space Weather Groups

Dr. Janet Green reviewed the task for this session: to continue to coordinate with other space weather groups and report on their activities to the HPAC. The three groups presenting were the Space Weather Advisory Group (SWAG), Space Weather Roundtable (SWR), and Space Weather Operations, Research, and Mitigation (SWORM) Committee.

<u>Updates from SWAG</u>

Dr. Tamara Dickinson, Chair of SWAG, thanked the group and said she would provide an update on SWAG activities, talk about membership transition issues, and review coordination concerns or suggestions. She noted that much of what she would say would be her personal view.

She reviewed SWAG members and their roles, which fall into end users, commercial sector, and academic buckets. Members were appointed by SWORM and chosen to have a broad range of views and represent the community; they are not governmental employees. They bring back the views of the community and advise SWORM, which is led out of the White House. A report released last April led to a new SWORM implementation plan and there is user needs survey currently underway, as tasked by the PROSWIFT Act.

Next was a high-level review of the SWAG report. It had 25 findings and 56 recommendations, 11 of which were prioritized. One key success was the placement of a space weather person at the White House.

The ongoing user survey was reviewed, including the sectors and how and why they were chosen by SWAG. The Science and Technology Policy Institute (STPI) helped conduct the survey and provides an anonymized summary for SWAG. SWAG is in the process of writing the report that will go before Congress and SWORM, and also be made public. Dr. Dickinson reviewed survey topics (surveys included some of the same questions across sectors and some sector-specific questions) and the sector co-chairs.

The GNSS sector survey activity is expected to continue over two years, the other sectors have completed the survey activities. The rollout is scheduled for April 16, 2024 at the Space Weather Workshop. In the near-term, SWAG will give advice on the STORM/STPI Scales initiative, take requests from SWORM for next activities, and decide what the group itself would like to do. SWAG is hoping to have an in-person meeting in DC in late summer/early fall 2024.

Under the PROSWIFT Act guidance on SWAG membership, current SWAG members are approaching the end of their terms and there are several transition issues to consider. Dr. Dickinson reviewed her assumptions about transition details, including that anyone can apply, some members will continue on, and some new members may join.

Dr. Dickinson then reviewed coordination/collaboration among space weather groups. She discussed the confusion in the community about roles of SWAG, SWORM, Roundtable, and Council – in addition to the roles of federal agencies (e.g., DoD, NASA, NOAA) – and thinks clarifying messaging to HPAC should continue. Dr. Harlan Spence suggested the use of an infographic for messaging and Dr. Dickinson agreed. Dr. Duncan said infographic charts are helpful and are available on the Council's website. She recommended a white paper and will take the idea to the next Chair's meeting.

Dr. Duncan invited questions. There were none.

Updates from SWR

Dr. Sarah Gibson, co-chair of SWR, introduced the Roundtable team and gave her reflections and summary of their activities. SWR was formed in response to PROSWIFT and facilitates communication with SWORM, the academic community, and the commercial SW sector. She reviewed overlap and interaction with other space weather groups and noted that SWR is not FACA and does not make recommendations, which allows for deep dives on orphan issues, which are those with acknowledged need but no clear responsibility/path/funding.

Dr. Gibson noted that, within the last 12 months, SWR meetings have always started with presentations from coordinating groups. She reviewed the sessions at the June 2023 meeting and the discussion themes that emerged: what the new R2O-O2R workforce looks like; the familiarity of themes and recommendations; and the desire to increase intentionality in prioritizing, planning, and sustaining the space weather enterprise.

Dr. Gibson then reviewed discussion themes from the January 2024 Roundtable meeting sessions. The group talked about benchmarks and scales and the modeling gap analysis. She highlighted the discussion around Task 2 and said there was a great report from Cislunar and Beyond – Radiation Environment that provided members with a deeper understanding of what NASA was doing within the broader space weather enterprise.

The discussion themes that emerged from this meeting included improving communications between research and operations; R2O2R current issues and, specifically, the tabletop exercise O2R, for which SWR is interested in coordinating a workshop, including with the SWC. The SWR also had a closed session regarding the engagement between civil and DoD, and now they want to open it up to talk about synergies.

Dr. Gibson reminded everyone that the SWR can convene workshops and then reviewed current funding and appointments. The SWR considers communication to be key and their deep dive topics are inspired by other groups. The hope is to shine a light and provide information that can be useful to other groups in their evaluations.

Dr. Korreck sought questions. Dr. Duncan stated that the SWC had an idea to connect the civil gaps and the DoD gaps and it would be good to have SWC members discuss that in that forum. Dr. Vourlidas expressed an interest in more detail on the R2O2R, so they could use those on the tasks related to HPAC. Dr. Gibson said they would do that through connected members using the notes from that session. Dr. Green said she could convey that information but not in a written form.

Update from SWORM

Dr. Duncan introduced Jinni Meehan, Assistant Director for Space Policy in the Office of Science and Technology Policy, and SWORM co-chair.

Dr. Meehan reviewed the mission of the White House Office of Science and Technology (OSTP) policy, which includes advising the President; advancing American science and technology; working with federal departments and agencies and Congress; engaging with external partners; and ensuring equity, inclusion, and integrity across the board. Dr. Meehan highlighted the focus by this administration on international collaboration.

The Strategy & Action Plan was updated in 2019. The associated implementation plan was rewritten using the SWAG report from April 2023, and that implementation plan was just released by the Vice President at the National Space Council meeting.

Dr. Meehan reviewed the objectives of the implementation plan and mentioned their associated actions. She also presented a few projects that were not included on the presentation slides. R2O2R is important to the community and the ceremonial signing of the MOA between the four agencies (NASA, NOAA, NSF, and DoD) specifically addresses how they could work together to streamline the R2O2R valleys of death, get the applied research into operations, and get the operational needs back to the researchers for better products and forecasts. There is a need to stand up the testbed with SWPC, which will be a critical component for R2O2R. Testbed exercises have been happening already.

She also discussed updating the space weather scales funded by NOAA and being used globally. NOAA is planning to host meetings to talk about the space weather scales in Ireland, the UK, and Australia. They will also participate in the COSPAR meeting in South Korea and will host an "Americas" meeting in DC (including South America, Canada, and the U.S.). STPI will provide a recommendations report to NOAA on the best path forward on that project. SWORM will take a key role in getting federal input for this multi-year project, which will seek community input in year one and execute to products and services in year two.

Because this administration recognizes the importance of the benchmarks, the Department of Homeland Security (DHS) has committed to fund the initiative in parallel with space weather scales. Another thing informing products and services will be the Congressional report on the user needs survey from SWAG. Finally, Dr. Meehan underscored that the SWORM deeply supports the TTX that will take place in May 2024 and mentioned that the SWORM will also take part in an Australian exercise and remains involved with international partners.

Dr. Meehan talked about memberships which roll off in December 2024. She noted that this committee cannot do staggered memberships; there must be 15 appointments all at once. The existing 15 members have to express interest and resubmit, if desired. There is a fast-track action committee within the White House that will determine the best makeup of the team.

Discussion, Topic 1

Dr. Mehta noted the importance of all the exercise activities and believes it is critical to understand areas that are lacking and advancement. He would like to see an interactive or succinct way to highlight the points that address how the agencies can improve their R2O2R activities, informed by impacts and causes. Dr. Meehan agreed.

Dr. O'Brien asked about the mechanisms to overcome institutional inertia, specifically how to ensure that these agencies, with competing priorities and existing cultures, will do things differently than they have in the past 20 years. Dr. Meehan suggested the question is about prioritization. The work of SWORM is to inform the budget process by presenting the priorities of the nation/administration. Then, it is up to the agencies to make it happen. The one-NOAA approach is an example of movement that has been made to bring lines within NOAA together to work on agreed upon priorities. The MOA helps identify how to leverage missions of other agencies to carry a successful mission with R2O2R. She mentioned that maintaining communications and engagement between industry and academia is also critical.

Dr. Halford mentioned that, within the space weather community, especially in regards to international collaboration, some data comes from sources who are less willing to be open in public. She wondered whether there is a way to encourage other groups to be more open to making data public, regardless of borders. Dr. Meehan said yes and that NASA and NOAA have open data and every product is public. They have been pulling private sector data to improve models, but there needs to be discussion about what proprietary data can be released publicly. This could be modeled on engagements with international communities and their data. She added that multi/bilateral conversations with other countries are not uncommon. The Solar System Ambassadors (SSA) is working hard on getting international agreements to include data in their systems, and the space weather community could piggy back on their efforts. Dr. Halford followed up regarding the Heliophysics data resource library taking in data produced by both NASA and others that can benefit NASA science. Their charter says they'll be respectful of limitations of data science providers, but there's a tension with regards to open science that needs mitigation.

Dr. Mehta wondered whether there is a need to partition resources from the agencies directed to science versus operations and suggested that that discussion might fit well into the Task 5 discussion. He also wondered whether there could be a funnel that is space weather impact-specific, in the spirit of

implementation. Dr. Meehan thought that was interesting and noted that, in updating space weather scales, NOAA intends to update the entire product suite and go impact-based and that's right in line. Dr. Meehan would leave that to SWPC colleagues to consider.

Dr. Harlan Spence asked about the confusion among various groups. Dr. Meehan has heard from the community that there is confusion; but, although it's clear in laws, charters, descriptions of agency roles, and executive orders what groups are tasked to do, working knowledge of other group activities is both lacking and critical to success. Dr. Duncan underlined this issue of community confusion, the complicated space, and different players. She suggested that the SWC could consider a recommendation to further communicate these differences. Dr. Green noted how much information there is and thought that having it in the PROSWIFT Act might not be enough; she proposed publishing a white paper in a journal. Dr. Spence said he has some confusion, too, and that these three presentations were helpful; he suggested a shorter version for the larger community. Dr. Vourlidas mentioned an attempt to do this in 2022, but noted that it went unpublished; he agreed to the idea of undertaking it now.

Dr. Duncan announced the move into the working session for Topic 1 and explained the process.

Working Session on Topic 1 for SWC
[No notes were requested for the working session.]

Topic 2: Next Steps in Addressing Space Weather Science and Modeling Gaps
The meeting reconvened at 2:00pm and began with brief introductions of the SWC members.

- *Dr. Paul O'Brien*, of the Aerospace Corporation, has scientific interest in radiation belts and the application of our knowledge about the space environment to satellite design and operations.
- *Dr. Janet Green* is with Space Hazards Applications and her interest is space weather impacts to satellites.
- *Dr. Harlan Spence* is the Director of the Institute for the Study of Earth Oceans and Space at the University of New Hampshire. His space weather interests are from sun to mud.
- *Dr. Michele Cash* from NOAA Space Weather Predictions Center has a background in the magnetosphere and physics and is interested in the R2O transition.
- *Dr. Angelos Vourlidas*, from Johns Hopkins APL, has a background in coronal mass ejections, coronal physics, and space instrumentation.
- *Dr. Nicole Duncan*, from BAE Systems, is the chair of SWC and has a background in high energy flare physics.
- *Dr. Kelly Korreck* is a program scientist at NASA HQ and the designated federal officer for the SWC. She has built instrumentation and did science to study space weather.
- *Dr. Alexa Halford* is from NASA's Goddard Space Flight Center (GFSC) and is the ITM lab chief there. Her background is in the magnetosphere, sun to mud, and looking at different types of space weather impacts.

- *Dr. Piyush Mehta* is an assistant professor at West Virginia University. His background is in the thermosphere and satellite drag modeling and, in the last few years, data science, machine learning, and space weather in general.

- *Dr. Ronald Turner*, from ANSER, has a background in radiation risk mitigation, especially for astronauts from solar events.

- *Dr. Daniel Baker* is the Director of the Laboratory for Atmospheric and Space Physics at the University of Colorado at Boulder. His areas are all aspects of space weather and space policy.

- *Dr. Jamie Favors*, from NASA HQ and the new Director of the SWP, has a background as a meteorologist and in fluid dynamics. He is invested in space weather and, interest-wise, in human exploration and R2O2R.

Dr. Duncan reviewed the remaining agenda for the day and turned the meeting over to the next panel.

Modeling Gaps & Operator Perspective

Dr. Vourlidas introduced the afternoon panel and reviewed the ask from HPAC: Discuss the possibility of a space weather gap filling analysis and provide recommendations.

Dr. Noé Lugaz, a research professor from the University of New Hampshire, began his presentation by reviewing risks and recommendations from past gap analyses and the most important new observations that have been identified. He talked about the need for cost-benefit analyses in space weather. The first recommendation for gap filling is the use of observing system experiments (OSEs) and, although efforts have been made in the community, there is a need for better visibility and funding schemes.

Dr. Lugaz reviewed some examples regarding forecasting Bz, for which there is a need to know how much accuracy and lead time is desired, and high-speed stream forecasting, for which there are many methods (e.g., remote sensing, modeling, machine learning, etc.) From the work over the past decade, it is not known which is best. For some problems, a new type of data is needed, whether polar observations or a new instrumentation. OSEs are not possible without the observations to do it; so for some problems OSSEs are necessary, although simulations can be hard to get funding for. After OSSEs have been done, the next step is to get onto a science mission.

Over the past 4 years, a good understanding of the critical questions has been developed. Dr. Lugaz said with the current budget constrains (i.e., without a clear path possible to $1B+ HPD funding), it is necessary to determine the optimal way to improve things. Although there are answers to specific needs, such as improving Bz forecasts or getting within 24-hour lead times, there needs to be a lot of investment. The key question is what is best: something small to improve a couple hours or something to improve to 24 hours with much bigger errors?

Dr. Mehta liked the idea of a cost-based priority approach. He wondered, if you have the approach and one form of impact per possibility, should there be consideration of the additional part of the impacts on operations if it is possible to achieve the expected impact. Dr. Lugaz said customers often want things that are not realistic. For example, if your goal is to have a 2-day arrival time with 10-minute error, that's not realistic. The research side and conversations with end users about priorities are both necessary. It's all part of the cost-benefit analysis and carefully putting the impact into the discussion.

Next, Dr. Slava Merkin, the Director of the NASA DRIVE Center for Geospace Storms, began his presentation about the perspective of a global geospace modeler by clarifying that he will be presenting his thoughts only.

Dr. Merkin said that all space weather targets or impacts in geospace, in regards to predictive models, have a global geospace model that may drive other predictive models (e.g., radiation environment or geomagnetically induced currents [GIC] calculation). He described what is needed to move from science discovery mode to predictive mode. Because geospace is a complex system with multiple/many domains, there will always be incomplete physics in the models. The solution will be fusing models with all possible sources of data, but without traditional methods of assimilation.

Dr. Merkin gave some examples of what the community is already doing and promising directions. There is a need to increase the amount of data everywhere possible. There is an issue of non-uniform data sampling in geospace, a lot of data near the earth and much less farther out. There will be a need to develop data ingestion and assimilation methods, which is beyond current knowledge. He reviewed examples including the use of historical data, wave data models, and the combination of all the data sets in the atmosphere; all of these processes are in initial stages.

Dr. Spence noted that, in terms of missing physics, some is invisible and unimportant but some might be fundamentally important. He then asked, based on assessments and development of models, are there some aspects of the missing physics that could be important and would be a target? Dr. Merkin said yes, that reconnection remains a big unknown in the magnetosphere, and it is the least explored area in terms of fixing it by supplying more data to models. A more straightforward example is inner-magnetosphere waves, because there is a lot of data and wave models can be used to inform global models in a very specific way. Dr. Merkin added that ionospheric conductance is one of the biggest unknowns in global modeling that affects the global state of geospace greatly.

Dr. Turner asked, regarding reinventing data assimilation, whether there is something unique about space weather data that would create a barrier between the space weather community and the billions of dollars of tools being developed in the artificial intelligence (AI) world to address generic problems; or, will we be able to take advantage of more generic AI machine learning data assimilation techniques in space weather? Dr. Merkin said it is the latter: We should be able to take advantage of the methods; they should allow us to create synthetic data to populate the system with the necessary density of data.

The next presentation came from Mr. Bob Arritt of the Electrical Power Research Institute (EPRI), where he leads the geo-magnetic disturbances research as it impacts the bulk power system in the United States, and for international customers, including those in Canada. Mr. Arritt reviewed some industry questions, such as how to prepare for storms, predictions about size and likelihood of storms, what is the accuracy of that prediction, what the impacts may be, are we doing everything we can. At EPRI they deal with things that may impact reliability or cause power blackout, and geomagnetic disturbance (GMD) has demonstrated its ability to disrupt normal power delivery.

Mr. Arritt reviewed what they prepare against. In the last 10 years, the industry has developed the benchmark event, a 1-in-100-year storm definition, which NASA was critical on. Planners work towards that storm but also consider what they would do in an even bigger event. It all goes back to operations, which are more versatile as procedures can be changed; there are planning studies to inform operations. But, all of this depends on getting the forecast in enough time to make appropriate decisions. Those actions are very limited if you have only a 1- or 2-hour notification for a storm.

He then talked about the importance of knowing the impacts of these large weather events. Most of the analysis on the power system is geared towards answering the compliance requirements from the North

American Reliability Council that oversees the reliability of the power system. So, by regulations, they have to perform the vulnerability assessments: the analysis, the monitoring, validating models, all driven by the space weather. There is a benchmark provided by NASA which provides information on the type of storm they're preparing against. The storm profile and forecasting is the input to the model which drives the response on the ground.

He reviewed the projects undergirding a resilient, reliable power system. They have a blocker project with the DoD that blocks the GIC currents; it's costly and takes a lot to maintain-- whether it becomes widespread is to be determined. He then reviewed what he sees as the key answers to the GMD preparedness for the bulk power system: collaborative research, industry meetings, NERC's GMD meetings, NASA engagement, DOE engagement, NSF engagement, and NOAA collaboration.

Dr. Turner asked Mr. Arritt to speak about the cost, in more than just dollars, to a power company of a false alarm. Mr. Arritt said various numbers go to operational awareness, but more important than the cost alone is the operators taking the awareness of threats seriously, which can be diluted by false forecasts. Many operators that experienced the last big event, in 1989, have retired; there is a need for operational awareness – when the transformers become saturated they go up 20-40db in noise and the first response can be "we need to turn it off." You need to know to ride through it, or actions can lead to blackouts which can prolong things and increase costs.

Mr. Arritt was asked, if the government is willing to pay for the solution by deploying space weather monitoring, modeling, and forecasting resources, why would industry make any investment on its side to mitigate the risk? What is the balance between industry investing to solve these problems and space weather science and space weather operations solving these problems. Mr. Arritt answered that utilities are following studies to take action and meeting regulatory requirements to protect their assets and ride through events. So, industry studies focus on the 1-in-100-year storm. If they have a vulnerable transformer, they would spend the resources to address it. Industry is doing what it needs to do via regulations.

Dr. Baker wondered whether, given the benchmark scenario, there is still examination of other variants of that, meaning seasons or external driving conditions (adverse winter weather, extreme summer heat) on the system. Mr. Arritt said yes, analyses are required to be done at peak and shoulder load and also the different configurations they may be in when they're supplying peak or not supplying peak load and all different kinds of scenarios are run, which has an effect on the computational intensity. When you're running the various analyses and tripping off an asset, you have to rerun your analysis without certain assets.

Dr. Mehta asked whether the space weather community is trying to contribute to improving these models, predictions, and forecasts. And, also, what are the priorities that need to be addressed, what are the space weather outputs desired to feed into the analysis tools, and what are the downstream processes space weather could enhance? Mr. Arritt said, in a perfect world, you can get a warning days ahead of time, including the intensity, that can be translated to an electric field, so operators can run a model as the system is configured when the event happens. Also, accurate prediction of the size of the storm is helpful. Currently, there is dependence on the magnetometer measurement, which is sparse; it's near-real time because it's more historical data and anticipation. He said that they do use the geospace operational products that SWPC puts out and that it all boils down to the speed and accuracy of the prediction.

Dr. Halford asked whether the gap could be more quickly and easily fixed with more magnetometers or by having improvements with the models. Mr. Arritt replied that they use magnetometers more for planning purposes, but there are a lot of limitations in the power industry to incorporating magnetometers on the operation. Dr. Halford asked about whether the best way to make improvements to improve

actionable information is it to invest money in model improvements or provide more data access and accessibility? Mr. Arritt said both. Dr. Mehta said that forecasting is primarily a model thing that can be made better by data; and Dr. Halford countered that models have physical inputs that need to go in.

Dr. Vourlidas asked whether there are formal requirements for that forecast, 2 hours ahead or more, and with what accuracy? Mr. Arritt said something may come days ahead of time and it will be a near miss. Certainty is not possible until within an hour; so, that one hour, there's really not much you can do other than increase operational awareness. Dr. Vourlidas asked about minimums or maximums that make forecasts actionable? Mr. Arritt said some things you can do within a day, some things within 2 days. Two days would be great, but he wouldn't draft that as a formal requirement: it's always the more the better. He added that they could draft a standard, if necessary.

The next presentation came from Jonah Colman, Space Environment Mission Lead from AFRL. He is the outward looking face for the research team and regularly meets with other DoD and intelligence agencies. Recently he has been interested in interfacing with NOAA due to the expansion of commercial space which makes the future of NOAA look more like DoD space weather, with lots of assets in space, worth a lot of money.

Dr. Colman reviewed some things about space doctrine at the public release level: space domain awareness is where Space Force sits: characterize, warn, and respond to space-related behaviors and activities that threaten the Unites States; in the original SPACEPOWER doctrine space weather is called out specifically. Dr. Colman reviewed electromagnetic spectrum operations, including the electromagnetic operational environment and the intervening medium, which is impacted by terrestrial and space weather.

After discussing the definition of the word "operational," Dr. Colman reviewed the DoD space weather capability desires, which may or may not be conscious needs. The desires fall under the general categories of assessments, forecasts, and specification and predictions for various events; surveillance, geolocation, and communications systems; and impacts.

Dr. Colman described working with the DoD and how he solicits and gathers end user needs to synthesize those needs into use cases. He asks is there a user, is the user doing something important, and can you help them? He then reviewed components of successful technology transition and reviewed considerations on development and vetting of models and systems before providing them to operational users.

Dr. Baker noted that a lot of things space weather has become dependent upon are not operational systems but rather NASA or other agency assets and asked how worried and how desirous Dr. Colman is of an operational Sun-to-Earth 24/7 observational system? Dr. Colman said he doesn't think of those satellites as operational and it's hard to think of a NASA satellite as being truly operational. He would prefer (for NOAA and commercial space, as well), if the thing that goes up satisfied a particular use case.

Discussion, Topic 2

Dr. Mehta opened the discussion for Topic 2. Dr. Spence asked Mr. Arritt what the opportunities are for the commercial side to engage with international partners. Mr. Arritt said there is significant international interaction with, for example, Canada, European entities, Norway, and New Zealand, which has been at the vanguard of GMD analysis. About assets that are not operational but are useful, something like SMAP, Mr. Arritt said that monitoring critical to get the ground truth. If you can measure the GIC, you see what gets coupled and what the magnitudes are, then you can compare it to the bean field and you can see what's driving any discrepancies. GMD analysis is very much relative to other power system analyses

and is in the early stages. The tools he presented have just been developed in the last 5 years and they are still doing benchmarks and doing field data to understand where the discrepancies are.

Dr. O'Brien said the power industry has a whole modeling piece after space weather and then asked what is the preventative action going to do to the rest of my network? How would space weather people, researchers primarily in the geospatial phenomenon of nature, tap into that tail end piece? Does this forecast actually improve your calculations? You can't do the value assessment unless you understand the end user's experience. Mr. Arritt said it has to be a collaboration because utilities can't just hand their models over. It's really an effort of working at the same table, getting the inputs and understanding. It's hard to get a real system model because of security. EPRI's role is interfacing between the science community and utilities to do the research and understand the impacts. Dr. Mehta pointed out that this question highlights the question of what operations actually means / is the forecast useful. Dr. Lugaz agreed with Mr. Arritt: the easiest way to answer the question regards legacy measurement: the same quality measurement provided 3 hours earlier should be useful, but a new type of measurement is much harder. Dr. Baker remarked to Dr. O'Brien that his understanding was that one of the strengths in terrestrial weather is having centers where forecasters and users really work together so they can see what a forecast implies for the workings of terrestrial systems. And this is one of the things that is probably really needed in space weather: to have a place where users and forecasters and an entire apparatus feeds back.

Dr. Halford asserted a need for ground-based instruments. She said maybe one of the Council recommendations should be that HPAC should look at the limitations to NASA being able to help fill those gaps, that are also needed in order to complete NASA research in the R2O pipeline. She asked Mr. Arritt whether he would see the addition of ground-based instrumentation and the data that could come to that as value-added to research/end goals/user needs? Mr. Arritt said yes, they like measurements and more data is better for large events. One of the difficulties in utilities is resource constraints; it's always good to have more information. Dr. Colman said that needs a cost/benefit analysis. The idea that putting satellites into orbit is the only way to do space environment monitoring seems wrong, especially in light of software defined radio systems that can monitor large chunks of the electromagnetic spectrum and be used flexibly in a transmit and receive mode for various applications at the same time.

Dr. Mehta said perhaps there should be an impact-based classification or segregation. In terms of getting researchers and operators together, maybe come up with a list of actual operation models and products, do an analysis on what would be missed, what does it do, does it make a difference? Then, see if there is a place for mature technologies to be improved or upgraded for quick operational impacts? That's where the R2O program should be going, although this may not be the purview of this group. It's hard for the community to make impacts if we try to do everything in the same funnel.

Dr. Lugaz said he thought there are gaps that fall within the NASA portfolio which are farther from operations but are space weather research-related. R2O and some of the connections to NOAA and operations are better done now. In response to a question from Dr. Duncan about whether this is something specific or a reference to analyses that have not been adequate, Dr. Lugaz replied that it is adequate according to the ask; it may not have the most important impact but is the most cost-effective way to invest in improving space weather but may not be mitigating the highest risk. Dr. Mehta: agreed

but said benefit to the end user should be considered: is an improvement in your model or forecast performance helpful to the operator? Dr. Vourlidas said the fault is not on the research side, there is not clarity from the users on what they need. The users have their own models that are independent of us. Dr. Mehta countered that what is done should be informed by user needs. There was disagreement about whether this was already happening via the user survey or in another way. Dr. Halford offered that those needs might change in the future. Dr. Vourlidas asserted that the NASA needs are the ones to work with, whether they need to protect their infrastructure or astronauts in space. Dr. Mehta asked why NASA needs to focus only on that and said that R2O is more than space weather.

Here, Dr. Westlake explained how R2O2R is working via the steering committee and interaction between the agencies. NASA solicitations for space weather are driven by conversations with SWPC which are driven by their interactions with users or their understanding of particular parts. He said it is currently working pretty well. Dr. Cash said this is where operations informs research and, ideally, requirements come from end users and customers. The goal of the testbed is to be able to bring in your end users, model developers, and forecasters to determine what the needs are and how they can be met. Dr. Mehta wanted to address that what NASA funds is not necessarily just for NASA use; it's more for the wider space weather enterprise. Dr. Vourlidas maintained that, if there is prioritization, it is necessary to start with what NASA needs, because that is who the SWC advises. Dr. Halford attempted to clarify: when someone applies on a proposal, it may be an industry asset or NOAA, they will have different needs. The communication for research needs to be consistent between the researcher and them. When setting metrics, baselines, benchmarks, that is more broad in terms of national security and that is the SWAG. Dr. Duncan said SWAG survey users are the end users. Dr. Mehta sought clarification by asking how NASA invests its resources in the R2O program? Dr. Duncan said that part of prioritization should come from what the impacts could be and what the users are asking for. Some, but not all, will come from user needs assessment. Dr. Duncan then suggested identifying selection criteria NASA will use to prioritize topics for R2O2R grants. Dr. Vourlidas said that, at this point, the group was talking about gap filling.

Dr. Baker brought up the situation, about a week and a half old, of a coronal mass ejection with estimated speed that would suggest it would reach 1au in about 13 hours or so. He asked what Mr. Arritt thought the power providers would have done with that knowledge, if it were directed at Earth. Mr. Arritt said vulnerability assessments are still being worked through. It would go into operation procedures for this type of event; each utility is different, but all of them have some operational plans in place. Dr. Baker and Mr. Arritt agreed that much less than 13 hours is not a lot of time to react.

Dr. Lugaz suggested that "NASA space weather" and O2R2O are not synonymous and there is a space for NASA space weather beyond O2R2O. NASA should be interested in improving forecasts even if it doesn't help the end user at this time, but improving forecasts could be useful in the future. Dr. Mehta agreed but also thinks there should be a split between science and operations. Dr. Westlake suggested that that is a bigger than SWP question: that it is HPD, conversations with LWS, and clarifying for the community.

Working Session on Topic 2 for SWC

[No notes were requested for the working session.]

Adjourn

The meeting adjourned at 5:00 p.m.

Friday, February 23, 2024

Overview of Agenda
Dr. Duncan welcomed everyone and thanked the group for their work the previous day before reviewing the agenda for the day.

Public Comment Period
The public comment period began at 9:05 a.m. There were no public comments.

Topic 4: Interagency Space Weather Science
Dr. Duncan introduced Topic 4 and turned the meeting over to the leads, Dr. Paul O'Brien and Dr. Dan Baker. Dr. O'Brien mentioned that the topic was originally interagency but has picked up a portion of R2O2R, as well. He introduced Dr. Elsayed Talaat, to speak on the One-NOAA strategy, and Dr. Lawrence Friedl, who would then present on the Earth Science applications.

One-NOAA Strategy
Dr. Talaat has a dual role, the Director of the new office of Space Weather Observations at NOAA, as well as the System Program Director of Code 490 at Goddard, which implements the NOAA/NASA programs to establish space weather observations. Dr. Talaat reviewed NOAA's mission, to protect life and property on Earth and in space, and the products and services it provides.

As defined by legislation, NOAA is responsible for monitoring, forecasting, data archiving, and research to support operations. At NOAA 2023-2027, the effects of space weather will take priority among other well-recognized challenges.

Dr. Talaat emphasized that observations are the backbone of forecasting and warning capabilities, and that NOAA relies heavily on partnerships to do their work. Dr. Talaat reviewed the partnerships on the ground and the partnerships and assets that NOAA has in space.

NOAA has established space weather as a new strategic objective, within NESDIS, with the goal to advance space weather observational leadership in LEO, GEO, and extended orbits, and consistent with the agencies responsibilities. There is a nascent effort, along with NWS and OAR to work on a joint strategic post.

The new strategic objective culminated in the establishment of the Office of Space Weather Observations. Now, NOAA is managing two programs dedicated to NOAA Space Weather capability and these have matured from ad-hoc efforts and secondary payloads to primary missions and primary payloads for space weather observations. This office manages the Space Weather Follow-On Program and Space Weather Next program, managed by CODE 490 at Goddard.

Dr. Talaat discussed SWFO's role and mentioned that the first part will be the Compact Coronagraph (CCOR) that has been integrated as part of the GOES-U spacecraft scheduled to launch in a couple months out of Kennedy. Because of the critical need for coronagraph measurements, CCOR is going into operations right away. The other mission is the SWFO L1 mission to succeed the Discover satellite to be the first dedicated operational space weather satellite, scheduled to launch on a rideshare with NASA IMAP launch in 2025.

The SWFO program includes development of state-of-the-art HP instruments. NOAA is also responsible for ground segments for space-based assets. They have just completed the construction of two new antennas, which will do the command for SWFO L1 and receive data in the American sector. They are

also building antennas distributed around the world and partnering with various international agencies to bring resilience to the system.

The Space Weather Next (SW Next) program will maintain and extend space weather observations, from a continuity standpoint in LEO, GEO, and L1, but also will expand capability to a partnership at L5 and others.

To help define the goals for the next generation of space weather capability, NOAA is doing user engagement and stakeholder collaborations. They are tracing space weather observations to user needs and benefits. So, for instance, that's how NOAA defined what they're doing for the Space Weather Next, L1 Series, and this process is underway. For L5 there is collaboration between NOAA and ESA to manage CCOR-3 development effort, integration of the instrument into ESA's Vigil mission (scheduled for 2030), and development of data services. This will give a stereo view of the coronal mass ejections but also a view of the solar wind rotating towards earth, which NOAA defined in a major analysis is the biggest impact that NOAA can make on their observing and forecasting capability.

Part of NOAA's outreach efforts are Space Weather Prediction Testbed (SWPT) exercises to explore capabilities, needs, and gaps of current NOAA Space Weather products and services. This was done with the civil aviation community and satellite community. The goal is to accelerate transition from research to operations and to inform the operations to research process: a way to get direct feedback to and from the end user. Dr. Talaat discussed the space weather TTX to simulate a weather event with widespread impact on national infrastructure and to gauge national and local responses.

Dr. Talaat also discussed the development of the one-NOAA strategy among line offices, between NWS, NESDIS, and OAR. The need for a one-NOAA strategy is driven by the absence of a formal framework for modeling and observational capabilities from R2O2R. Despite a quad-agency agreement between NOAA, NSF, DoD, and NASA, without the necessary infrastructure at NOAA, they can't take advantage of all that research.

Dr. Talaat reviewed a visual of the cross-line office discussions to best implement this new strategy. While NOAA is investing in observations and has a forecast and space weather prediction center doing great work, these parts of NOAA are not working as they do for terrestrial weather, yet. This does not replace space weather research conducted by NASA or NSF, but enhances that platform to put the research into use.

Dr. Talaat reviewed what makes advancement hard and what accelerates advancement. He mentioned that NOAA is completing some R2O efforts within NOAA and leveraging what is in the community through joint venture and SBIR programs. He emphasized that NOAA is planning to use the GDC observations as a key R2O pathfinder. NOAA is hoping to use these observations to put real time data into the operational stream and bring it in through the testbed and processes to see how much more capability they can provide to end users and help define future operations.

NOAA has been supporting efforts related to Solar Sail Technology. This is the most important piece to provide more time/warning for end users to make decisions and, hopefully, there is a mission that could be used as a demo for that capability.

Dr. Talaat described a planetary system observing challenge. NOAA will maintain capability in geostationary orbit and are maintain or expanding capability in LEO as well, through partnerships and commercial data buys. They are also looking at partnerships in HEO and at L4 and partnerships at NASA to exploit this data through the R2O process.

Finally, Dr. Talaat mentioned the total solar eclipse on April 8, 2024, for which NOAA is holding events.

Dr. O'Brien invited questions.

Alexa Halford asked whether NOAA has plans to look for data in the geotransfer orbits, as that could help with doing satellite anomaly assessments. Dr. Talaat agreed that is a desirable data set. The priority for space weather observations in deploying NOAA assets were determined by SWPC and NOAA as the high-availability products (formerly KPPs) and those don't include the geotransfer orbit data as of yet. The focus is on HAPs which is L1 in geostationary. There will be assessments of core capabilities every few years with SWPC. NOAA would partner to get that data but right now has no plans. Dr. Halford noted that there is no sustained operational use of data but there also has not been sustained data from that region, so it feels like a cycle you can't get into. With the Van Allen probes gone, what does entry into the cycle look like: operational usage so you can get data so people trust the data will be there for forecasting? Dr. Talaat said what drives SWPC is end user demand. That type of observation is in list of things to do but isn't as high priority as other items.

Dr. Baker expressed delight that NOAA is stepping into its rightful role in space weather. He wondered, with the possibility of on-orbit failure of instruments, could SmallSats be an opportunity to fill holes. Will NOAA have its own small sat vitality program or will it rely on catching that from NASA or other agencies? Dr. Talaat said that, in LEO, the strategy is to be disaggregated and opportunistic. NOAA is investing in small instrumentation to fit on SmallSats but are resource limited and will try to take advantage of opportunities for hosting small instrumentation, possibly working with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the Taiwanese Space Agency, and others. NOAA may host on their own LEO birds; those would be single instrument deployments.

NASA Earth Science Applications: Lessons Learned

Dr. O'Brien introduced Lawrence Friedl, the Director of Applied Sciences, NASA Earth Science. Dr. Friedl joined NASA Earth Science in 2002 and was a program manager focused mainly on air quality issues and also coastal management, wildfires, and water management. He became Director of the Earth Science program in 2009 and set the strategic direction there. He has degrees in aerospace engineering and public policy and public administration. Another role is co-chair for the U.S. Group on Earth Observations.

This presentation afforded the opportunity for Dr. Friedl to reflect on the past 22 years. He mentioned that his presentation slides were dense so that they might be used for reference.

Dr. Friedl reviewed major takeaways (10) from his reflection. These included things like applications work is hands-on and about building relationships; apply the most relevant, and not necessarily latest or cutting-edge, science; and, also, consider reward structures to incentivize and recognize applications work. There are interagency and intersectoral groups looking at the examination of rewards structure so that doing societally-relevant community-engaged research can be seen as scholarship.

Dr. Friedl reviewed common terms, such as research, applied research, and applications. In Earth Science, they have defined science as a combination of research, applied research, and applications. He gave a conceptual example using the water cycle to walk through these three areas.

When Earth Science looked at these areas in the early 1990s, they considered the advancement of computing, GIS, and some commercial companies entering the area of Earth observations. They took a breadth-oriented approach to achieve broad exposure for Earth observations. Dr. Friedl noted that an analysis of breadth versus depth would be interesting for the SWC to tackle. Also, companies, NGOs, etc.

have incentives that can create multiplier effects. This may be happening more than we realize because these organizations may not always make their efforts public.

The metaphor for Earth Science applications was a bridge, although this oversimplifies the nature of the interaction of engagement: not always one clear path, and there are other issues (e.g., policy, institutional, budgetary). A better metaphor may be a looping highway exchange: a complicated pathway to connect research, applications, and users. This is an apt metaphor because users familiar with the space may not need support, but new users may need communications, directional signage, etc.

Dr. Friedl reviewed groupings for Earth Science applications: planning activities, monitoring and tracking impact, and alert systems and forecasts. He then discussed mechanisms for program and project support. He reviewed the professional trainings and DEVELOP project, which provides 10-week, rapid prototyping feasibility projects with nonprofits, state/local govt, and others for any field.

Earth Science learned to engage users by ask leading questions rather than broadly asking what people need. It's important to determine challenges and whether Earth Science information has value or whether redirection to commercial company or NOAA or ESA, etc. is better. Earth Science started with a system engineering approach but has determined that the human-centered design and design thinking is a better approach.

Dr. Friedl next discussed OPENET as an example of a the development of a new tool based on information gleaned from collaboration among many agencies and institutions to uncover a need and build towards it, rather than using a build-it-and-they-will-come approach.

Earth Science has done a lot to integrate applications into missions, which have moved from being driven by research interests to bringing in user communities earlier. This was beneficial for direct use and also a way to help users understand future research and how it could impact their work. Based on these learnings, Earth Science did four things: created a program applications lead (PAL); issued an Earth Science applications directive; included community assessment reports in pre-Phase A; and established the Early Adopters Program. The Early Adopter Program identifies users and gives access to proxy data; it also includes the use of detailed personas as part of the human-centered design process. He noted that the PACE mission successfully used personas to prioritize users and identify gaps.

Dr. Friedl emphasized that developing capacity is hands-on work. Among other things, the skills to develop an application may be different than the skills required to transition one. This is important for personnel decisions to ensure the relevant skills are available during the project.

Based on their learnings, Earth Science has developed an Earth Science Applications guidebook (handbook), which is available online. The division has also recognized that knowledge that is co-produced is much more likely to be used and that Earth Science is emphasizing co-production.

In recognizing that applications have connections to decision making and requisite value to society, Earth Science has captured stories and put them into a human-based narratives collection on the Space for U.S. website. The stories, that can be told backward from the research and mission that enabled data that was used, or forward from the societal value to what can be used to address it, highlight either the decision makers or the people who were impacted by the work. Earth Science has also tried to emphasize people's faces in communications to connect; Dr. Friedl believes that awesome sun or space images also meet this need.

Finally, Dr. Friedl reviewed the flow for Earth Science application developments and also reviewed major takeaways.

Discussion, Topic 4
Dr. Westlake talked about value of this presentation. He asked how Earth Science manages the relationship with NOAA to ensure that everyone stays in their swim lane or crosses appropriately? Dr. Friedl said there are many agencies working in the environmental space and Earth Science does not have a unique approach to NOAA. There are fewer agencies in space weather/NASA's space. A lot of earth science projects are not promoting only NASA data, they are much broader and try to promote the use of earth observations, overall. In the partnership space, having the open conversations and thinking about common objectives could lead to managing that relationship. NOAA was only left out, though not intentionally, because applications are broader.

Dr. Mehta complimented Dr. Friedl and his presentation, which Dr. Friedl noted is public and available. Dr. Mehta asked about the approach to engaging end users and even separate groups. Dr. Friedl said they went to where the users meet and convene. They had the luxury of 7 to 12 thematic areas (e.g., agriculture, water management, disasters, health and air quality, etc.) and a program manager who worked events and engagements for every area. Also, they made communities aware when solicitations were coming. We required all of our project solicitations to make users part of those projects, although there was a spectrum of involvement. There was a focus on government agencies based on the theory that they would help spread information to other constituents, but even interested individuals couldn't always champion broad incorporation and there were mixed results. That's the reason for broadening to NGOs and companies.

Dr. Green returned to the NOAA question and the development of applications that go directly to users [Dr. Friedl clarified here that he would say "with users."] She said it seems, in space weather, NASA's not allowed to do that, but has to go through another agency owing to congressional decisions. Dr. Friedl said that there is language in the NASA Organic Act about results of earth and the atmosphere and applications of those results. Specific language calls for doing this with other government and international agencies. Dr. Friedl offered to share the language Earth Science has used. In response to a question about weather, Dr. Friedl said that, since weather was well covered by the weather service and the research arm and things like SPoRT, Applied Sciences stayed away from weather, despite the recognition of the impacts of weather.

A discussion ensued of PROSWIFT and the source of the official government forecast and the associated amount of user engagement. NOAA is not in the business of that operational forecast, and it's the same for the NWS. Developing a large community of users will take all the agencies working together, maybe for instance through a feasibility project that builds into a user community in operational forecasting. The evolution of user engagement is important to all agencies. Dr. Vourlidas expressed concern about uses of space weather data for other than forecasting. Earth Science has a lot of uses that don't require forecasting, and there are uses for education. Space weather end users may be surprising if we truly investigated and understood.

Dr. Duncan said that what goes after the forecast is another space for application: how does the forecast impact the users? It's different than Earth Science because a lot of users for space weather are adept and have built their own systems, with the power grid, for example. She added that the work over the past 20 to 30 years in Earth Science is inspiring. Dr. Friedl acknowledged that this presentation did not include all the mistakes made along the way.

In response to a request for comment about the different needs of smaller missions, Dr. Friedl said Earth Science has required all directed missions (community missions) to do an assessment of user communities, and not just on technical interests, but also on risk tolerance and their characteristics. This is not just for pre-Phase A design but for the lifetime. Part of the reasoning is that there is more money for a

directed mission. There is also a venture class with an applications requirement, not for a community assessment report (although that's discussed, it may be too much for a PI-led mission to do) but for audience analysis to better understand application opportunities.

Regarding human-centered design, it can be a big cultural shift. Dr. Friedl said that's a fledgling effort and they are talking more about the idea of co-production, which is an integrated approach. He mentioned that there is a new effort called Earth Action, with a new director, that is looking to evolve the interactions between the research and applications communities. This style of work is not taught in academia, so perhaps training opportunities may be needed.

Dr. Halford asked, regarding user community engagement with missions, at what stage is it happening? Perhaps the pre-proposal stage is too early, but when do they come in to help define data requirements and formats? Dr. Friedl said they are going through that right now. The first missions living under this directive were the ones coming out of the 2018 Decadal. The community assessment report was done in pre-Phase A, by the end of pre-Phase A, they must have their community assessment done. Often it was recognizing that some of the user community needs aligned with what researchers wanted. A lot of interesting things were learned: for instance, one mission that had more precipitation and atmospheric items, we thought shipping companies would be big users. We learned companies like Fedex and DHL outsource their weather, forecasting, and planning, so we need to go to the community of companies that are outsourced to. In a few cases, a community identified a priority band that the research community realized would also help them. So, most of the time, users were involved at pre-Phase A so they could be part of the mission concept and represented at mission concept review. By the end of Phase A, the applications plan has to be prepared to be accepted for KDP-B. Dr. Friedl clarified that these are only directed missions; there's some other language for PI-led missions. Dr. Halford emphasized that bringing users in from the beginning engenders true partnership and equal engagement. Dr. Friedl said they recognize that the time from pre-Phase A to launch is long and we don't ask the organizations to be fully involved for all those years, but it's important to help them know key times when they can engage/give input. Early adopters are naturally more engaged. We heard that end users are surprised to be welcomed because they've been trained to just accept data that's available. Also, hearing about future missions, sometimes encourages end users to consider using existing data in the meantime.

Dr. Talaat suggested that a useful analogy to keep in mind is that Earth Science had a huge amount of untapped data, so these applications were able to connect the data with unmet needs. There is a need to think strategically about what data can meet unmet needs. He would love to hear about a community that needs data that we have or that a new mission would provide. Space Weather would love to have user feedback, too, which is currently hard to elicit.

Dr. Turner applauded NOAA and NASA's commitment to off-axis solar monitoring through L5 program and asked Dr. Talaat whether there was a requirements-driven assessment that said L5 was better than L4 or was it because ESA was going to L5 that we're joining L5 platform, especially in light of a wish for an L4. What drove us to L5, requirements-driven or target of opportunity? Dr. Talaat said both were drivers. There was an analysis regarding the most impactful new observations and it was off the sun-earth axis, coronal imagery. ESA, looking at where to fly their missions, did a priority analysis, from an operational and science standpoint, and chose L5, which provides a different vantage point than L4. They both give stereo view of the Sun and coronal mass ejections, but L5 is where sun is rotating towards us but L4 gives us early warning of solar energetic particle events. It was a collaboration with ESA, informed by several workshops.

Dr. Duncan asked how the broad cultural change and asked how that was approached. And, looking at science versus applications communities, in the 2024 budget situation, what advice would you give to HP to achieve cultural change? Dr. Friedl noted that it is easy to present clean development after the fact; but,

there has been some real tension between research and applications. There was initial skepticism about applications, but now the value is clear and, in terms of using Earth Science information, the research community has come along. Not all lessons have been through the applied sciences program; the research side has also done a lot on applications. SPoRT was funded through the research analysis program. Over the last 20 years there's been a societal shift to wanting to see the relevance of research. There was an attempt to showcase the research and missions that led to applications and an attempt to emphasize that you don't get the applications without the investment in research/tech/missions. Researchers with an interest in connecting their research to applications were often funded. Best case was a researcher who was ¾ funded by R&A and ¼ funded by applications, because they would be well-versed to speak to research colleagues and also user communities.

Dr. Vourlidas asked Dr. Talaat about plans to use the ground segment for SWFO to download data for NASA missions? The plan is to use the L1 antennas during the day, so the nighttime is free. NOAA is looking at how to enterprise the whole antenna system (internal discussion); it is being used for science missions but NOAA is considering how to exploit it for other operational missions. NOAA is contracting out the OCONUS antennas but could probably buy time. The antennas are not big enough for L4 or L5. In response to a question about whether the tech demo for the solar sail and logistics/programmatics is this done in collaboration with NASA tech development, Dr. Talaat said they were collaborating with the solar cruiser while it was still planned to be launched with IMAP. At that point, it was still in the NASA development pipeline; now that it needs to get back into a full scale development, there is discussion with NASA SMD and STMD, among others, about how to fund it. NOAA is currently funding some of the risk reduction tasks for the sail and different applications for solar sails, as well. Dr. Vourlidas said that there are instrument ideas that would be more appropriate for space weather application versus future NASA research capability and wondered if SWP could join the demo or development effort, or whether it was all NOAA? Dr. Talaat said there have been talks with NASA regarding the pipeline for instrumentation to be built and put on the shelf until needed. Some of the instrumentation is the same that NOAA wants in different operational space weather missions and there is a lot of interest to find applications for those.

Dr. Baker suggested that Dr. Friedl's presentation should be a roadmap for what should happen with SWP, with the 10 takeaways becoming a checklist for missions to meet for engagement in space weather and space climate. Perhaps Heliophysics should change its name to Space Physics and Applications to emphasize both areas. For Dr. Talaat he commented that the GOES program has some beautiful instruments making great measurements, but NOAA has no program for research and analysis associated with those; these are a number of data sets that are underused because there isn't a mechanism to exploit operational instruments fully for the data use in research. He said everyone needs to speak up about GDC and its great science and crucial data for space weather. Dr. Talaat replied that there is a need to find and exploit the large data sets, which may be outside the research missions but can still be found in, for example, COSMIC-2 and commercial data purchases for the ionosphere that NOAA provides to the world, similar to the GOES data. NOAA measurements, under the Office of Space Weather Observations, should be considered as part of the infrastructure of the science observatory that NSF and NASA uses. Earth Science has had some success with joint exploitation of ROSES calls with NOAA data: Living with a Star, Guest Investigator, ROSES should be opened up to NOAA data as part of the science effort right now.

Dr. Baker said maybe NOAA should have its own mission operations and data analysis kind of component. Dr. Talaat agreed that NOAA needs a research and development effort for sustained development of capability, as called for by the SWAG, but it's going to be focused by necessity and design.

This discussion ended and the group moved to a short writing period followed by the working session.

Working Session on Topic 4 for SWC
[No notes were requested for the working session.]

Topic 3: Space Weather Science and Deep Space Exploration
Dr. Duncan welcomed everyone back and introduced Topic 3 and the leads, Dr. Ron Turner and Dr. Halford. Dr. Turner introduced the panel: Dr. Janet Barzilla from the Space Radiation Analysis Group (SRAG) to discuss the Artemis needs and gaps, Dr. Leila Mays and Michel Romano from the Community Coordinated Modeling Center (CCMC) to discuss R2O for solar energetic particle (SEP) forecasting, and Dr. Tamas Gombosi to introduce the Clear Space Weather Centers of Excellence.

Janet Barzilla explained that SRAG is tasked with mitigating crew exposure to space radiation and then gave a brief review of SRAG's Artemis responsibilities. She highlighted the fact that gaps in the current technology have been identified and that there is a focus on understanding of SPEs and implications for other areas.

Her presentation provided a quick overview of all the gaps, but would focus on those related to space weather forecasting. The first set of gaps she highlighted were related to the understanding of the impacts on space radiation on crew health. She then reviewed a set of gaps related to vehicle design. Next were gaps related to the monitoring of the space environment. The final set of gaps she highlighted were related to space weather forecasting.

Regarding the radiation models and forecasting for SPEs, SRAG wants to increase both warning times and accuracy of real-time operational forecasting, but also want to predict all clear periods because understanding whether an event will not happen in the short term is important. (This is an example of the near-term gap being addressed.) SPE modeling fosters understanding of the impacts of a short-term increase in that environment, both for acute health effects and also for the decreased likelihood of long-term health effects, and care needs to be taken not to under- or over-predict.

There are currently three funded projects to address these gaps. She reviewed the gap closure activities and how they're important for to understanding and modeling of the SPE environment. She provided an overview of one of the products of the ISEP project, which is a scoreboard that shows models of SPE intensity for a recent event, March 28, 2022.

Dr. Barzilla addressed the gap of earth-independent space weather forecasting and crew alert systems, which is more of a mid-term gap, applicable to later missions where there are longer periods where ground communications are not possible. The purpose of this gap is to develop a real-time autonomous forecasting software fed by assets that are not ground-based, and it gives the crew more autonomy to understand the environment. The impact is similar health-wise as the gap addressing SPE modeling; but there is the added difficulty of delayed response time moving further from the Earth environment.

One funded project that addresses the improvement of modeling capabilities, through the Hermes suite of measurements, is a collaborative effort between SMD, HEOMD, and STMD. Three other activities are seen as necessary but are currently unfunded.

Dr. Barzilla provided a visual roadmap that addresses both gaps, the SPE modeling and earth-independent crew alert system. Eleven gaps have been identified that effect SRAG's ability to effectively support Artemis missions. She reiterated that the fact that the Artemis mission occurs in free space requires advancements in SRAG's ability to protect the crew; the closure of gaps requires development and incorporation of new technologies.

Dr. Turner opened the floor for questions.

Dr. Mehta thanked Dr. Barzilla for the talk. He noted that this is a complex challenge with interplay between data/models/instruments and a desire to have nowcast and forecasting capabilities, with an idea to develop sensors through different locations in the heliosphere and use those to develop an autonomous system for forecasting a radiation environment where humans are. He wondered if we get those measurements, is there a parallel model that would be going that these data would feed into and how is that model development currently occurring, what data is it using, synthetic? What are the plans for that? Dr. Barzilla said that, in some cases, current model developers are being encouraged to use other instruments available. Their model is in use, using Advanced Composition Explorer/Electron, Proton, and Alpha Monitor (ACE/EPAM) data, but they are interested in progressing their model to use alternate satellite inputs. Dr. Mehta asked whether those inputs are currently available or are they to include part of the sensors still planned? There are models in place using available assets, but the data is not available to transition those models to use planned assets because they've not been flown (e.g., Hermes and Ida). There was discussion about whether that is a location with an existing data stream and clarification that, no, the Hermes tool will be flown with the vehicle. Dr. Mehta wondered if it's not flown, how will it be incorporated into the model. Dr. Halford attempted to clarify by asking where the models are used in forecasting operational actions and where the data come into play. The models are used to help with planning but data might still be used as a final decider for whether the radiation environment is okay to do the necessary operation. How much are the actions being determined by what's in a forecast model versus just the data without the model, and how do those two intersect? Dr. Vourlidas attempted to clarify the models have the same data that is being flown now to what is in Hermes. Dr. Halford asked what the operations look like, and what do people actually use? There was some discussion between Drs. Mehta and Barzilla about the use of data from different locations for modeling versus operations. Dr. Mehta asserted that they are connected and operations should be driven by models. Dr. Barzilla said that, currently, for ISS SRAG recommendations are driven by data; right now, the models are used for situational awareness and there is hope to gain confidence in the models. Operations are currently based on GOES. The two agreed that it is currently nowcast, not forecast. Dr. Mehta asked whether the model development for forecasting is currently happening and what data source is expected to feed into those models. Dr. Barzilla replied that models that give us more ability to forecast are being developed; the data currently feeding those models are all ground-based processing, however further into Artemis, there is a hope to use assets such as Hermes and Ida, to feed those data streams. There was discussion about whether latency is to be expected in the process and discussion about the meaning of latency: once you start collecting data on these instruments there will be a period of model development to be able to use this data. Drs. Barzilla and Mays agreed that the understanding from the model developers is that there would be a calibration period.

Dr. Turner then introduced Dr. Leila Mays, who discussed some shifts in the Moon to Mars (M2M) Office and also introduced Michel Romano from that office. Dr. Mays provided a brief overview of the ISEP R2O Process for Human Exploration, which is a collaboration between SRAG, CCMC and M2M. The ISEP project began in 2018 in anticipation of Artemis, for which they didn't have any models. They looked at what was running in the research community and have transitioned over 10 models and built a web application to visualize them. These models are in use right now for ISS and Artemis support.

Mr. Romano reviewed the M2M Space Weather Analysis Office, including what they do as part of the NASA strategic in-house R2O2R pipeline. He noted that they have a growing relationship with NOAA SWPC to make sure there work is transferable to operational agencies. He then reviewed M2M space weather support activities, including real-time monitoring of space weather activity; documenting observations, analysis, and model outputs (all publicly available); and, as requested, 24/7 extended space weather analysis coverage for NASA missions. Then, Mr. Romano introduced the M2M Space Weather

Analysis Office team and mentioned the transition, with Yari Collado-Vega leaving and Theresa Nieves Chinchilla stepping in to the role of Acting Director.

Dr. Mays presented a diagram of the NASA in-house R2O pipeline, created by M2M and SRAG. She reviewed the activities along the pipeline, including bringing in models, builds, transitions, testing, and analysis.

She also provided snapshots of the SEP Scoreboard, which showed probability forecasts, heatmap and timeline, proton intensity, and binary forecasts converted into a display for SRAG. There is an existing flare scoreboard and an interest in flare forecasts; this software is being revamped to be able to bring in more models for more situational awareness.

Dr. Mays provided an overview of the CCMC-SWPC Proving Grounds, where there is a shared environment to transition models to test bed and, potentially, operations. EUMETSAT has been selected for testing, due to work done it was fairly straightforward to transition this to the CCMC-SWPC proving ground. The team is also looking forward to the Mars Space Weather collaboration, with real time MAVEN data, and wants more Mars data to understand how new models can be developed for Mars.

Dr. Mays then discussed the Space Weather Gap Analysis Report and said there is agreement on the SEP part of the Gap Analysis. The gaps outlined in that report are the first to consider, and she added several to take into consideration in the categories of SEP model inputs and SEP model development. She said the funding to develop models can take a few years.

The ISEP process has worked well to have the three groups (CCMC, SRAG, M2M) working together and with the model developers are essential. Dr. Mays noted that improvements have been made based on forecast skills and bugs feedback from all parts of the team. After noting the many things that are working well, she reviewed what needs improvement. Finally, she noted that models with the best forecast skill and usefulness to operators are prioritized.

Dr. Korreck thanked the presenters. Dr. Duncan said she appreciated the graphic showing how proving grounds interact with operations and, regarding the ace proving ground, there is a lot of good collaboration going on. She noted that UMASEP is an example of comparison, model selection, and SWPC transitioning that into operations. M2M can run a variety of models that SWPC would not, but taking the one that seems most robust and shows the most promise has been a good success story. Dr. Favors mentioned that this is a great collaboration that has developed trust and problem solving among the groups.

Next, Tamas Gombosi, a professor of Space Science at the University of Michigan, began a presentation about CLEAR on behalf of Lulu Zhao, the PI, who was unable to attend. He noted that the average age at CLEAR is still early career scientist. CLEAR is a recently selected Space Weather Center of Excellence and is the only one that focuses on the inner heliosphere and, especially, space radiation. He reviewed CLEAR objectives for all clear SEP prediction and the SEP research goals. The core of the team of about 30 scientists is at Goddard and the University of Michigan and is interdisciplinary team of old developers, observers, theoreticians, and statisticians who lead the machine learning aspects.

Dr. Gombosi gave an overview of CLEAR, which uses empirical models, machine learning models, and physics-based models. The team is actively working on machine learning models for both flare and CME forecasts and making very good progress with about 24-hour forecasts. Model integration is done through a high-performance space weather modeling framework. The first level of forecast they are trying to do is all clear, because that's very useful; they are also forecasting peak fluxes and several energy ranges for proton fluxes that SWPC and SRAG cares about. Because this is a 4π system, forecasts can be made

anywhere in the solar system and can change the energy ranges per interest. The center of this is the Space Weather Modeling Framework (SWMF), which is plug-and-play, modular, and has components that are easy to replace.

Next, Dr. Gombosi talked about the major weakness of the model and biggest missing piece for improving the physics-based models: it is driven by the 4π solar magnetograph. The NASA Space Weather Gap Analysis identified gaps in observations and research, and Dr. Gombosi reviewed those.

Discussion, Topic 3

Dr. Turner asked how well SRAG works with CCMC on model development: do they take what CCMC has to offer and run it or does SRAG have its own modeling development underway that's independent of CCMC and M2M's modeling activity? Dr. Barzilla said SRAG is not currently doing any individual SEP model developing, however it is actively involved with CCMC and M2M and the individual model developers as part of ISEP. Dr. Turner asked about using dosimetry measurements to estimate parameters for astronaut radiation protection, sort of nowcasting? Dr. Barzilla said they do use dosimetry measurements but not to develop space weather models, except for an acute radiation reach tool that is a model specifically of radiation exposure using current dosimetry. The actual measurements go into the astronauts' exposure record. Dr. Turner was under the impression that dosimeter measurements could be used to determine the radiation environment inside the module. Dr. Barzilla said that there are internal models used for ISS but not advertised. When there is an SPE, the assessment of the exposure is not as good as where the cutoff regions are, where the crew could be told to take shelter. Dosimetry is used for exposure models, not space weather models; there is also a risk model being used.

Dr. Turner asked Dr. Gombosi about all clear forecasting, which can be done with thresholding, a balancing act of certain models, but SEPs are rare. He asked anything is looking at the solar surface to determine what might tell you that today is not going to be a solar particle event. Dr. Gombosi said the CME/flare forecasting is doing that with machine learning. He added that the most dangerous SEP events are accelerated in interplanetary space, so just looking at the solar surface is not a good predictor. But for the all clear, if we can forecast that the sun will be relatively quiet in the relevant region, then we can make a 24-hour prediction.

Dr. Duncan asked Dr. Mays about the NASA/R2O pipeline and what role NASA, HPD, or the SWP play within that space. Dr. Mays said the project is monitored, along with the project under ISEP and work with SWPC, through monthly status reviews. There are also bi-weekly tag ups with Dr. Fisher, Dr. Favors, SRAG, M2M, and Hermes. There was a discussion about grants and whether the models you that are transitioned will be through many types of grants, exclusively through NASA HP or other entities. Dr. Mays said the would source from everywhere: NSF, NASA, DoD, SBIR, or it could also be an international model that got the grant a different way.

Dr. Duncan asked whether the process for passing a modeling gap or a need back to the funding agencies (e.g., HP) was working and also about prioritization and how it is coming through the process. Dr. Mays said for some things, yes, smaller urgent blocker needs that are raised are often addressed. And everyone wants more coordination on grant outcomes and deliverables. But there are some longer-term problems that are completely solvable but need a team and funding and those bigger picture, longer-term things may get lost. So far, proposals have been built from a grassroots level. Dr. Duncan said an urgent need around human exploration was identified at the last meeting, and there is a desire to understand whether the process is working in a way that appropriately addresses the needs we've identified.

Dr. Favors sought to connect a couple points made during the meeting: under PROSWIFT the R2O2R steering committee is an interagency thing that gets together to define what you see in an R2O2R solicitation. Part of that is SWPC input but also SRAG input. Part of CCMC funding comes from the

SWP to do space weather things. How well it's working is probably subjective. Perhaps the R2O2R steering committee needs to be meeting more frequently for ideas such as expanding from one type of solicitation to different types of solicitations from space weather in the future, for example. He suggested thinking right now about things that could be different a year from now. Dr. Duncan expressed appreciation for the reminders that SWPC sits on the R2O2R steering committee and the concept that, having done this for a while, we are looking to the future.

Dr. Cassak asked Dr. Green about Hermes, which felt like only half the story on energetic charged particles. Is anyone developing imagers to address the concern that measuring in situ particles in the Mars corridor occurs too late to be useful? An imager would be vital piece. Dr. Favors said that part of the equation on using Hermes today was driven by mass allocation and what we had available on Gateway. Hermes is one of multiple payloads that will be flying on the first two modules on Gateway to get the realistic perspective of lower-, middle-, high-level energy particles. The remote sensing part of what future payloads would look like on human class vehicles going to Mars is part of this conversation, as is the whole Earth-independent capability. How well is human exploration playing with SMD and overall? Interactions with Hermes have built out a lot of good relationships, they moved where Hermes is on their modules to put us in a better location for science measurements, which was hard to engineer. That's one example of having HPD more in the room for these conversations and bodes well for future of conversations like these, for example, where remote sensing instruments are placed on payloads. Dr. Cassak said something like a compact coronal imager seems to need intentional instrument development, unless the plan is to re-fly an existing payload. It's much easier to give someone something off the shelf that propose something that is to be developed. Dr. Favors said that the human exploration architecture document has gaps right now that are real opportunities for requirements on external payloads, payloads on the surface, etc. An invitation has gone out for the Space Exploration/Space Weather Workshop at the end of April 2024. The workshop will be focused on this topic. Dr. Favors described the four high-level Heliophysics-specific objectives, one of which is Space Weather-specific, that drive that architecture buildout, along with other science disciplines.

Dr. Halford said that one of the issues is that community feedback has been going through the Planetary Division so outreach to the Heliophysics community has been hard: getting information about opportunities and what places exist for input and there isn't much advertising in SPA newsletters, for example. This could be the basis for a recommendation: communication about opportunities to get information into the architectural document. Dr. Favors said that fogginess is indicative of where the agency is right now. The workshop in April is designed to be hyper-focused on Heliophysics and Space Weather. Dr. Halford sought clarification of the boundaries between Planetary and Heliophysics when it comes to areas of expertise, using SEPs and charging of the lunar environment as an example of the communication challenge. Dr. Favors talked about a position for a person in the space weather program to focus heavily on human exploration. Exploration helps us do science; and we have to help exploration. Dr. Duncan suggested discussing this more within human exploration topics at the next SWC meeting. Dr. Halford suggested having someone from Jake Winter's talk about bridging the gap between that group and human exploration. Dr. Favors said he would feed information to HPAC and back to SWC about tasks that would be human exploration-related.

Dr. Turner asked Dr. Gombosi to expand on the gap of 4π coverage of the Sun and how that impacts our ability to forecast pending, not ongoing, events. Dr. Gombosi said that is a huge problem. If you put an imager on a Mars mission, that's still in the solar equatorial plane. The two big problems are the dark side of the sun and the solar poles. The polar regions are the origins of all the magnetic structures and the solar wind that we observe at 1au, and that's the least known. There are huge error bars because we have 7 degrees to look. It's nearly perpendicular to the magnetic field vector. There is no way out of a 4π solar mission if you really want to know the radiation environment, because now we basically use rotational tomography. Dr. Mays said the models that are using the in situ data are performing the best and the

performance of the other models, including pre-eruption models, is not great. There are measurements needed to improve those models but Dr. Mays does not believe they need to be on the vehicles.

Dr. Vourlidas said everything is pointing to the need of a gap filling analysis. There is some urgency to solve this particular problem. Dr. Green said that's a near-term need at SRAG. A suggestion was made to take a different approach, such as an agile or faster-than-light approach: Bring modelers and users together for a short-term project (e.g., 10 weeks) to see if it is possible to solve some of immediate issues, maybe improvements can be made on CME processing, for example. Dr. Mays said she thinks the efforts would need more than 10 weeks, but there should be some thought into how to tackle some of these issues within an ecosystem of groups working together, even if with independent grants. That's what they've done at a grassroots level through ISEP with CCMC, SRAG, and M2M, but some more structure would be useful. If there were a way to get short-term funding for a seed project (e.g., improving flare location, tackling the CME problem) that would help. Dr. Vourlidas gave the example of the LWS institute rolling grants for a couple years, where they brought scientists together for something like a few weeks per year. Dr. Mays added that buy in from the model developer (and user) helps develop ownership for the model and interlinking of resources to deliver something and keep in touch after the grant. Something like an institute gives people that feeling of ownership. Dr. Duncan said this was reminiscent of agile consortiums and problem-solving teams that Dr. Friedl discussed and thinks it is a good idea. Dr. Vourlidas wondered about accelerating the funding mechanism, which is a different issue.

Dr. Green said it sounds like Dr. Mays has specific needs that don't fall under R2O grants or science; she offered that she has done contracts for CCMC that were short, back-door style. Dr. Halford suggested a Heidi call for data and code but acknowledges that is usually open source code development. Dr. Green suggested a rolling unsolicited mechanism. Dr. Favors said SWP is currently thinking about engagement with users taking many different mechanisms.

Dr. Baker brought up the long-standing request for a pole sitter, looking at the pole of the sun, alluded to in the last Decadal and featured in recent NRC reports about space weather needs. It is necessary to enhance forecasting and Dr. Baker thinks a crash program is necessary to get it sooner rather than later, for instance, in 3 years rather than 3 decades. Dr. Halford agreed that the pole sitter is a great one but added there are many space weather missions needed for things like this, so maybe a recommendation is having a mission line. Rather than that, it was recommended that HPD look into alternate methods of funding on shorter time scales as well as for other needs.

Working Session on Topic 3 for SWC
[No notes were requested for the working session.]

SWC Report Out and Closing Remarks
The findings by tasks were posted and presented. There was a brief clarifying discussion between Dr. Luce and Dr. Halford about NASA engagement with others on Scales. Dr. Halford said that NASA should be aware of the Scales and understand the process of change.

Dr. Duncan thanked everyone for their attendance and work at the meeting and the agency for bringing everyone together. She mentioned that it was a valuable meeting and she would reach out to everyone for wrap up prior to sending results along. Dr. Favors said he would give the results to Dr. Westlake and Dr. Luce first. Dr. Luce commented on the rich agenda, nice format that clearly informed discussions. In the future, it may be beneficial to structure feedback on recommendations. Dr. Westlake expressed his thanks and Dr. Favors stated his excitement for the meeting and its learnings.

Adjourn
The meeting was adjourned at 5:08 p.m.

Appendix A
Participants

Space Weather Council Members
Nicole Duncan, Ball Aerospace, *Chair*
Kelly Korreck, NASA Headquarters, *Executive Secretary*
Daniel Baker, University of Colorado
Michele Cash, NOAA Space Weather Prediction Center
Janet Green, Space Hazards Applications
Alexa Halford, Goddard Space Flight Center
Piyush Mehta, West Virginia University
Paul O'Brien, The Aerospace Corporation
Harlan Spence, University of New Hampshire
Ronald Turner, Analytic Services Inc.
Angelos Vourlidas, Johns Hopkins University Applied Physics Lab
Daniel Welling, University of Michigan

Other
Mattie Anastopulos
Robert Arritt
Melissa Ashe
Irfan Azeem
Janet Barzilla
Carlos Braga
Darcia Brown
David Cheney
Ian Cohen
Jonah Colman
Debra Dajon
Gina DiBraccio
Tammy Dickinson
Jeanette Edelstein
Chris Englert
Elizabeth Esther
Jamie Favors
Genene Fisher
Galen Fowler
Reiner Friedel
Lawrence Friedl
Heather Futrell
Katherine Garcia-Sage
Manolis Georgoulis
Sarah Gibson
Tamas Gombosi
Edward Gonzales
Tony Iampietro
Jared Leisner
James Lochner
Margaret Luce
Noé Lugaz
Janet Kozyra
Amy Marshall
Leila Mays
John McCormack
Jinni Meehan
Slava Merkin
Dan Moses
Asal Naseri
Teresa Nieves-Chinchilla
Bill Paterson
Evangelos Paouris
Simon Plunkett
Arik Posner
Elena Provornikova
Antti Pulkkinen
Doug Rabin
Carolina Ravinskas
Amy Reis
Ursula Rick
Kayla Rillo
Richard Rogers
Michelangelo Romano
Andrew Rowe
Roger Sanchez
Sabrina Savage
Sara Schwartzman
Guillermo Stenborg
Shelley Stover
Elsayed Talaat
Walter Twetten
Joe Westlake
Bradley Williams
Emma Williamson
Lisa Winter

Appendix B
Council Membership

Nicole Duncan, Chair
Ball Aerospace

Kelly Korreck, Executive Secretary
NASA Headquarters

Sage Andorka
United States Space Force

Daniel Baker
University of Colorado

Michele Cash
NOAA Space Weather Prediction Center

Janet Green
Space Hazards Applications

Alexa Halford
NASA Goddard Space Flight Center

Piyush Mehta
West Virginia University

Paul O'Brien
The Aerospace Corporation

Harlan Spence
University of New Hampshire

Ronald Turner
Analytic Services Inc.

Angelos Vourlidas
Johns Hopkins University
Applied Physics Lab

Daniel Welling
University of Michigan

Appendix C
Agenda

Thursday, February 22, 2024		
9:00	Welcome from Heliophysics Director	Joe Westlake, NASA HQ
9:05	Ethics Training	SWC Members
10:05	Welcome from NASA Space Weather Program Director	Jamie Favors, NASA HQ
10:15	Welcome	Nicole Duncan, Ball Aerospace, SWC Chair
10:20	Adoption of the Minutes of Last Meeting	SWC Members
10:30	Comments from the Heliophysics Advisory Committee (HPAC)	Christoph Englert, HPAC Vice-Chair
Topic 1: Coordination with Other Space Weather Groups		
10:45	Updates from SWAG	Tammy Dickinson SWAG Chair
11:00	Updates from SWR	Geoff Crowley & Sarah Gibson SWR Co-Chairs
11:15	Updates from SWORM	Jinni Meehan SWORM
11:30	Discussion of Coordination	
11:50	Working Session on Topic 1 for SWC	
12:45	Lunch Break	
Topic 2: Next Steps in Addressing Space Weather Science and Modeling Gaps		
14:00	Modeling Gaps & Operator Perspective	Noé Lugaz Slava Merkin Bob Arritt Johan Colman
14:40	Discussion	
15:30	Break	
15:45	Working Session on Topic 2 for SWC	
17:00	ADJOURN	

Friday, February 23, 2024		
9:00	Overview of Agenda	Nicole Duncan Ball Aerospace, SWC Chair
9:05	Public Comment Period	Virtual Only
Topic 4: Interagency Space Weather Service		

09:10	One-NOAA Strategy	Elsayed Talaat, NOAA
09:40	NASA Earth Science Applications: Lessons Learned	Lawrence Friedl, NASA HQ
10:10	Discussion	
11:00	Working Session on Topic 4 for SWC	
12:00	Lunch Break	
Topic 3: Space Weather Science and Deep Space Exploration		
13:00	Space Weather Science and Deep Space Exploration Panel	Janet Barzilla Leila Mays Michel Romano Tamas Gombosi
13:40	Discussion	
14:30	Break	
15:00	Working Session on Topic 3 for SWC	
17:00	ADJOURN	