Space Weather Advisory Group Meeting 4

January 18 - 20, 2023

This webinar is a SWAG public meeting and will be recorded and transcribed. If you have a public comment, you acknowledge you may be recorded and are aware you can opt out of the meeting.

Welcome!

- In accordance with section 60601 of the PROSWIFT Act - NOAA established the SWAG to advise the White House SWORM Interagency Subcommittee

- All 15 non-governmental representatives of the SWAG, were appointed by the SWORM Subcommittee with 3-year terms beginning on October 1, 2021

- Each SWAG member here today serves as a representative member to provide stakeholder advice reflecting the views of the entity or interest group they are representing. The PROSWIFT Act directs SWAG members to receive advice from the academic community, the commercial space weather sector, and space weather end users that will inform the interests and work of the SWORM

Roll Call

SWAG Nongovernmental End-User Representatives

Tamara Dickinson, SWAG Chair
Science Matters Consulting

Mark Olson
North American Electric Reliability Corporation

Michael Stills
United Airlines (retired)

Craig Fugate
One Concern

Rebecca Bishop
Aerospace Corp.

SWAG Commercial Sector Representatives

Jennifer Gannon
Computational Physics, Inc.

Conrad Lautenbacher
GeoOptics, Inc.

Seth Jonas
Lockheed Martin

Kent Tobiska
Space Environment Technologies

Nicole Duncan
Ball Aerospace

SWAG Academic Community Representatives

Tamas Gombosi
University of Michigan, Ann Arbor

Delores Knipp
University of Colorado, Boulder

Scott McIntosh
National Center for Atmospheric Research

Heather Elliott
Southwest Research Institute

George Ho
Johns Hopkins University Applied Physics Laboratory

Welcoming Remarks from the Chair

Dr. Tamara Dickinson
SWAG Chair
Nongovernmental End User Representative
President, Science Matters Consulting


National Weather Service
36.4K Tweets
Follow
Official Twitter account for @NOAA's National Weather Service.
Details: weather.gov/twitter
United States
weather.gov
Joined January 2012
317 Following
3M Followers
Tweets
Tweets & replies
Media
Likes
National Weather Service Retweeted
NOAA Space Weather @NWSSWPC · 45m
Happening now! The SWAG is at DOC to discuss efforts to improve the ability of the U.S. to prepare for, mitigate, respond to, and recover from space weather phenomena. NOAA Administrator Rick Spinrad delivered remarks to the advisory group. Visit weather.gov/swag for more
Space Weather Advisory Group (SWAG)
Meeting at the Department of Commerce
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Australian Open 2023

Recap of Meeting 3

- Sector briefings on questions and processes for user survey
  - Reached consensus on the user survey questions and process
- Input from NOAA Social, Behavioral, and Economic Sciences Group
- Update from the SWORM co-chairs
- Quick update on related activities
- Discussion of how to get community input to our activities
- Discussion on how to gather information regarding our task to provide the SWORM with input as they update the strategy and action plan
- Public comment session
- Approval of March and June SWAG notes (Decisional)

Agenda Day 1

- Welcome and Recap of Meeting 3
- Progress Since Meeting 3
- NOAA Administrator Remarks
- SWORM Co-Chair remarks
- Committee Discussion
- Roundtable and Council Updates
- Current Status of Implementing the National Space Weather Strategy and Action Plan
- Lunch 12:00 - 1:00 PM ET

Agenda Day 1 (continued)

- Session 1.1: *Observational Data and Access (Ground Based)*
- Session 1.2: *Economic Assessment*
- Break 3:00 - 3:30 PM ET
- Committee Discussion
- Closing Remarks
- Adjourn Day 1

Agenda Day 2

- Welcome and Recap of Day 1
- Session 2.1: *Observational Data, Access, and Infrastructure in Space*
- Session 2.2: *Benchmarks, Metrics, and Scales*
- Lunch 11:45 - 12:45 PM ET
- Session 2.3: *Data Infrastructure and Methods*
- Session 2.4: *Evolving Infrastructure Systems and Services*
- Break 3:00 - 3:30 PM ET

Agenda Day 2 (continued)

- Session 2.5: *Industry and Government collaboration, Coordination, Outreach, and Communications in Space Weather*
- Public Comments
- Committee Discussion
- Closing Remarks
- Adjourn Day 2

Agenda Day 3

- Welcome and Recap of Day 2
- Committee Discussion
  - Findings/Recommendations
  - Writing Assignments
  - Next Steps and Timeline
- Closing Remarks
- Adjourn the Meeting

User Survey
Progress Since June

User Survey Progress

- Paperwork Reduction Act Process
  - First Federal Register notice posted August 16, 2022
    - Open for 60 days
    - No comments
  - Second notice to be posted soon
    - Open for 30 days
    - Adjudicate any comments
  - Send to OMB for approval
- Starting to work on the implementation plan
  - Will be holding a call with sector leads to talk about some options
- Hope to be able to actually conduct some focus groups at SWW 2023

User Survey Progress

<u>Held Town Hall at AGU (Dec 22)</u>

- Rebecca (GNSS), Kent (Human Space Flight), George (STM), Scott (Research) and Tammy
- Several SWAG members in audience and on-line
- Good audience participation

<u>Held a session at AMS, ran as a Town Hall (Jan 23)</u>

- Rebecca (GNSS), Kent (Aviation), Mark (Power Grid), Scott (Research), Jinni, and Tammy
- Several SWAG members in the audience
- Good audience participation

<u>AMS Town Hall – Spotlight on Space Weather Risks and Resilience: Preparing for Solar Cycle 25</u>

- Tammy, Jim Spann, Mary Erickson, Mona Harrington, Ezinne Uzo-Okoro, and Jinni

Opening Remarks
NOAA and SWORM Leadership

NOAA Administrator Remarks

Dr. Rick Spinrad

Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator

SWORM Co-Chair Remarks

Dr. Ezinne Uzo-Okoro

Assistant Director for Space Policy, Office of Science and Technology Policy

Co-Chair, Space Weather Operations, Research, and Mitigation Subcommittee

SWORM Co-Chair Remarks

Mary Erickson

Deputy Assistant Administrator for Weather Services,
Deputy Director, National Weather Service

Co-Chair, Space Weather Operations,
Research, and Mitigation Subcommittee

SWORM Co-Chair Remarks

<u>Mona Harrington</u>

Assistant Director, National Risk Management Center, Cybersecurity and Infrastructure Security Agency, Dept of Homeland Security

Co-Chair, Space Weather Operations, Research, and Mitigation Subcommittee

Committee Discussion with NOAA Administrator and SWORM Co-Chairs

BREAK
10:30 – 11:00 AM ET

Updates from Related Groups

Space Weather Roundtable Co-Chairs

- Geoff Crowley (Orion Space)
- Sarah Gibson (UCAR)

NATIONAL ACADEMIES Sciences Engineering Medicine

The National Academies Space Weather Roundtable

Geoff Crowley, Ph.D. (Co-Chair)
Sarah Gibson, Ph.D. (Co-Chair)
Art Charo, Ph.D. Space Studies Board

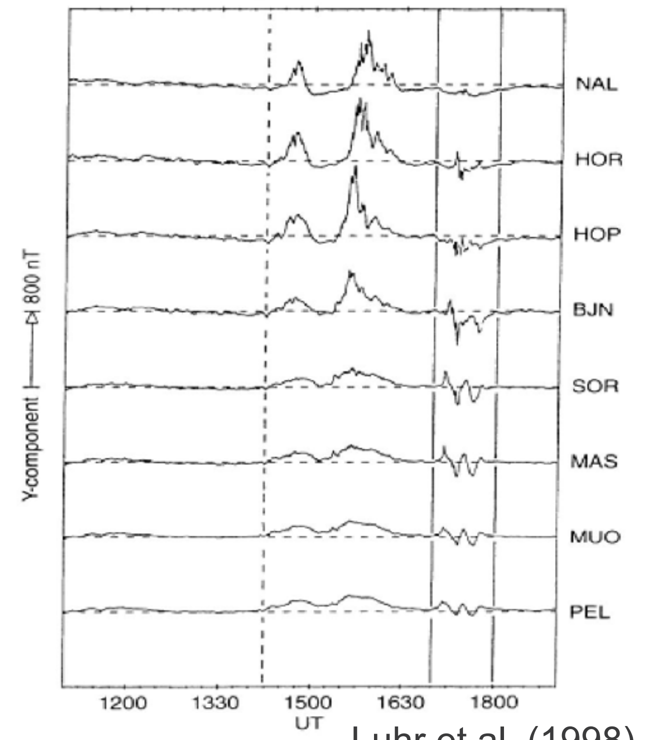
Space Weather Roundtable

- Diverse Membership
  - "Business as Usual" is not in the National Interest
  - Brainstorming group – generate ideas for other committees
- 1st In-person Meeting October 14th, 2022
  - Reports from SWORM, SWAG, Space Weather Council
  - Space Weather Enterprise Overview
  - Issues in R2O-O2R (TRL levels; AUL levels; 'Valley of Death')
  - Ground-based Space Weather Observations
  - Issues in Space Weather Data Buys
  - OSSEs (Observation System Simulation Experiments) vs OSEs
  - Reanalysis of the Space Weather System
- Monthly calls

	Art Charo
	Sarah Gibson
	Geoffrey Crowley
1	Anthea J. Coster
2	Delores Knipp
3	Drew L. Turner
4	Geoffrey D. Reeves
5	Hazel M. Bain
6	Janet C. Green
7	Jennifer L. Gannon
8	Justin C. Kasper
9	Leonard Strachan, Jr.
10	M. Granger Morgan
11	Mark H. MacAlester
12	Michael Starks
13	Shasha Zou
14	Louis J. Lanzerotti
15	Louis W. Uccellini
	Mangala Sharma (NSF)
	James Spann (NASA)
	Elsayed Talaat (NOAA)

November 29th Telecon: "Ground-Based Magnetometers"

- ❖ Guest Speakers - Jenn Gannon (CPI), Jeff Love (USGS), Mike Hartinger (SSI)
  - o What is a magnetometer?
  - o USGS network in CONUS (exquisite measurements)
  - o Other networks, including CPI commercial capabilities (less accurate, low cost)
- ❖ What are applications of magnetometer data? Who are Users?
- ❖ Who funds magnetometer networks?



Luhr et al. (1998)

Key Outcomes

- ❖ Magnetometers provide a very low-cost insight into space weather
- ❖ Measure important parameters relevant to Power Grid
- ❖ Important for space weather research (e.g. assimilation)
- ❖ Real-time data needed for real-time space weather applications/mitigation
- ❖ Need more magnetometers for better picture of ionospheric currents, E-fields & GICs
- ❖ Some ideas about developing a magnetometer consortium (Mike Hartinger)
- ❖ Jeff Love offered to set up a meeting with Head of USGS (Dr. Hayes)

Other Ground-based Instruments not well-supported: Solar telescopes, Neutron monitors

Space Weather Roundtable - Future Topics

1) R2O-O2R (TRL/AUL; OSSE's)

- ❖ There is clearly an operational need in various areas
- ❖ What do the Users need, and do they know its available?
- ❖ What is role of Government development, versus commercial and academic development?
- ❖ How do we take advantage of capabilities developed under the SBIR, R2O2R and other programs?
  - Data: Ground-based magnetometers, Ionospheric Scintillation Monitors, Solar Observatories
  - Model Prediction/Specification: Solar Flares, Satellite Drag, Electron density

- ❖ How do we transition capabilities? What skills are needed?
- ❖ Who should pay for the transition to operations?
- ❖ Who has the skill set to transition data and models

2) Talk to Users/Operational Community in more detail (after SWAG survey is completed)

3) Lots of other ideas

Updates from Related Groups

NASA Space Council Chair

- Nicole Duncan (Ball Aerospace and SWAG Member)

SPACE WEATHER COUNCIL (SWC) UPDATE

Presented at the SWAG MEETING 1/18/2023

Nicole Duncan on behalf of the SWC

*ALL OPINIONS PRESENTED ARE MY OWN

SPACE WEATHER COUNCIL (SWC)

- Established by NASA as means to secure the council of a community of interdisciplinary space weather experts on topics relevant to the HPD space weather program
- SWC acts as a community-based forum to coordinate community input and provide advice to NASA HPD via HPAC
- SWC is a FACA subcommittee to HPAC, and is responsive to actions levied by its parent organization

- Chair: Nicole Duncan (as of 1/1/2023)
- Designated Federal Officer: Jesse Woodroffe
- Council Members: Michele Cash, Alexa Halford, Sage Andorka, Piyush Mehta, Angelos Vourlidas, Janet Green, Paul O'Brien, Dan Baker, Ron Turner

2022 SWC ACTIVITY SUMMARY

- SWC held two meetings
  - 3/2/2022 (telecon): Inaugural 'Meet and Greet'; discussions w/ HPD leadership regarding the remit of SWC; brainstorming. Details are given in the meeting notes compiled by J. Woodroffe.
  - 8/24/2022 (hybrid at HQ): First in-person meeting. Main topic of discussion were the HPAC requests to the SWC. The meeting notes are available online.

- SWC brief to HPAC – 9/21/2022
  - Progress on the HPAC requests to SWC presented
  - No formal conclusions or advice provided to HPAC

- SWC brief to SWR – 10/14/2022
  - Introduced SWC
  - Provided summary of key discussion topics and progress

2022 PROGRESS ON HPAC ACTIONS TO SWC

- Look into SWORM, SWAG and SWR activities.
  - Established coordination plan among SWAG, SWR and SWC chairs – including coordination calls & reciprocal meeting invites to brief memberships
  - Jesse Woodroffe (SWC DFO) initiated white paper describing roles and responsibilities of each group
- Conduct (or commission) a gap analysis of space weather science, modeling and applications
  - Discussed existing 2021 NASA HPD SWx Gap Analysis, 2021 & 2022 NASEM SWx Operations and Research Infrastructure Workshops and ongoing SWORM benchmark and prioritization activities
  - Next meeting with address scope of task, prioritization criteria and dovetailing with Decadal recommendations
- Look for synergies with NASA's Artemis and space biology efforts
  - Conducted informational interviews with Moon2Mars and SRAG
  - Identified several topics for continued discussion: M2M office growth, Astronaut safety for crewed missions, gap analysis for cislunar radiation environment, preparing for Mars missions and payloads for lunar surface science
- Look for interagency and international cooperation opportunities
  - Domestic cooperation addressed by SWAG/SWORM
  - SWC has not discussed International opportunities yet. Possibilties include ESA Vigil, CSA AOM, Gateway, KASI SNIPE

BACKUP

RECOMMENDATION ON SPACE WEATHER COUNCIL ACTIONS AND DIRECTIONS (2 OF 2)

The HPAC recommends the following actions for the SWC:

1. SWC is advised to research the activities of SWARM and SWAG, identify overlaps and gaps, and determine how SWC can complement and leverage ongoing efforts, with specific relevance to the interests of the NASA Heliophysics Division. This may include researching reports on the committee websites; attending their public meetings; organizing a meeting of committee chairs and staff; and defining how the role of the SWC can complement the work of these existing committees.
2. Of specific interest to the HPD and HPAC is an analysis of the gaps in space weather fundamental science, modeling and impacts. Gap analysis studies have been performed by different agencies within the last decade, and a summary review of this material is of importance for HPD future plans. Specifically, the HPD supports development of a range of instruments at different technology readiness levels. Up-to-date understanding of knowledge gaps will assure that HPD can make an informed decision in prioritizing development of certain technologies, instruments, and models.
3. The SWC is advised to address the NASA's ARTEMIS and space biology programs to determine the potential to extend our knowledge with lunar focused space weather measurements and studies.
4. The SWC is advised to work on the development of specific suggestions for interagency NASA-NOAA-NSF-DoD cooperation in order to maximize return on investment in research infrastructure supported by agencies. Specific examples include development of suggestions about better coordination between NASA and NOAA supported space-based instruments and NSF-supported ground-based infrastructure, data fusion from multiple instruments, data assimilation efforts, etc.

SWC CHARTER

The Space Weather Council Charter

The Space Weather Council (SWC) is established as a means to secure the counsel of community experts across diverse areas, on matters relevant to space weather in support of the NASA Heliophysics Division (HPD). The SWC serves as a community-based, interdisciplinary forum for soliciting and coordinating community analysis and input and providing advice. It provides advice to the Heliophysics Advisory Committee (HPAC).

The NASA HPD space weather strategic mission is to establish a preeminent space weather capability that supports human and robotic space exploration and meets national, international, and societal needs. This is done by advancing measurement and analysis techniques and expanding knowledge and understanding that improves space weather forecasts and nowcasts. Ultimately, the HPD enables the space weather forecasting capability that the Agency and Nation require, in partnership with NASA's Artemis Program and other Federal agencies, and international partners. This includes the development and launch of missions/instruments that advance our knowledge of space weather and improve its prediction, and the transitioning of technology, tools, models, data, and knowledge from research to operational environments.

The SWC shall be a standing subcommittee of the HPAC. As such, the SWC shall report to and be responsive to actions levied by the HPAC. As appropriate, the SWC may seek scientific and programmatic input from the heliophysics and space weather communities at large on matters relevant to their actions.

Examples of the broad range of activities relevant to space weather that the SWC may be called on to address include the following:

- Articulate key scientific drivers for space weather research including focused research-to-operations-to-research topics, strategic observations, and others;
- Evaluate expected capabilities and rideshare opportunities for achieving HPD goals;
- Evaluate HPD space weather goals and objectives;
- Provide input and advice on relevant HPD space weather activities such as actions drawn from the National Space Weather Strategic and Action Plan, collaboration with other national and international agencies, ground-based observations, and its role in the Artemis and human exploration endeavor.

Space Weather Panel - Helio Decadal

National Academy of Sciences: Decadal Survey for Solar and Space Physics (Heliophysics) 2024-2033: Panel on Space Weather Science and Applications Members

- Christina M. Cohen (Co-chair, CalTech)
- Paul O'Brien (Co-chair, Aerospace Corp.)
- Hazel M. Bain (NOAA SWPC)
- Thomas E. Berger (UC, Boulder)
- Yaireska M. Collado-Vega (NASA GSFC)
- Heather Elliott (SWRI) (SWAG Member)
- Maura E. Hagan (Utah State U.)
- Noe Lugaz (U. of NH)
- Juha-Pekka Luntama (ESA)
- Steven K. Morley (DOE LANL)
- Drew L. Turner (APL)
- Kathryn Whitman (NASA JSC)
- Michael J. Wiltberger (HAO NCAR)

Current Implementation Status of National Space Weather Strategy and Action Plan

Objective I: Enhance the Protection of National Security, Homeland Security, and Commercial Assets and Operations against the Effects of Space Weather

- **Space weather benchmarks and scales**
  - STPI - project plan envisions the SWAG as a key stakeholder for synthesizing and conveying needs of the user community
- **Model effects of space weather on national critical functions and associated priority critical infrastructure and national security interests**
  - Previous power grid vulnerability assessments may not have considered the full 3D effects of Earth conductivity structures
  - Need denser-geographic magnetotelluric surveys in high-risk areas
  - Need expansion of the USGS ground-based magnetometer network
  - Need magnetotelluric surveying in areas of Canada where there are significant interdependencies between US and Canadian electric infrastructure

Current Implementation Status of National Space Weather Strategy and Action Plan

- **Assess the <u>cost of space weather effects</u> on the operations and implementation of critical missions**
  - The "extreme" estimates in the Abt report - *Social and Economic Impacts of Space Weather in the United States* - do not necessarily reflect a Carrington-like event or theoretical maximum event; therefore, the SWORM recommends refreshing this report to focus on a space weather event based on recent assessments of maximum geoelectric fields.

Current Implementation Status of National Space Weather Strategy and Action Plan

Objective II: Develop and Disseminate Accurate and Timely Space Weather Characterization and Forecasts

- Ensure baseline operational space weather observation platforms, capabilities, and Networks.
    - Policies need to be developed to facilitate the transition of research and academic data collection platforms to operational agencies
    - Need free and open exchange of data related to the impacts of space weather on technological systems operated by the commercial, academic, and governmental sectors

Current Implementation Status of National Space Weather Strategy and Action Plan

National Academies - Space Weather Operations and Research Infrastructure Workshop, Phase I and II

Requested by NASA, NOAA, and the NSF - considers options for continuity and future enhancements of the U.S. space weather operational and research infrastructure

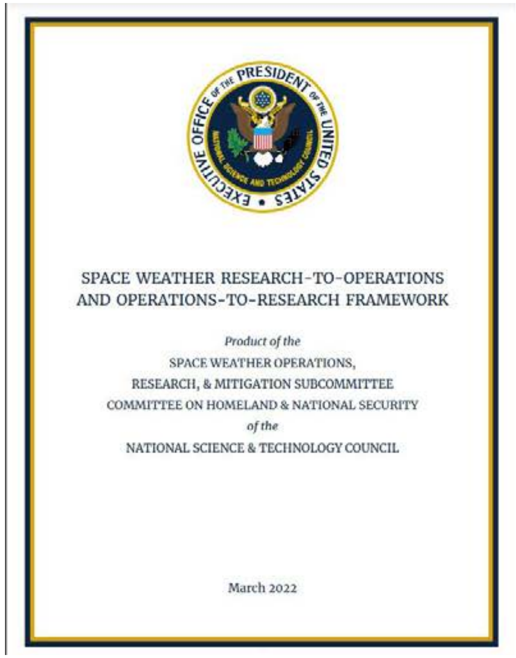
Addresses Strategic Knowledge and Observations Gaps

Current Implementation Status of National Space Weather Strategy and Action Plan

- Engage international partners to ensure space weather products and services are globally coordinated and consistent, as appropriate, during extreme events.
    - Space-weather event-specific protocol for the notification and situational awareness reports of space weather information during an extreme space-weather event are needed at national and international levels.

Current Implementation Status of National Space Weather Strategy and Action Plan

- Identify mechanisms for sustaining and transitioning models and observational capabilities from research to operations.
  - OSTP/SWORM release R2O2R Framework
  - NASA in partnership with NOAA and NSF continue applied research grants
  - 2023 Omnibus funds Testbest at $1.75 mil


EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES

SPACE WEATHER RESEARCH-TO-OPERATIONS AND OPERATIONS-TO-RESEARCH FRAMEWORK

Product of the
SPACE WEATHER OPERATIONS, RESEARCH, & MITIGATION SUBCOMMITTEE
COMMITTEE ON HOMELAND & NATIONAL SECURITY
of the
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

March 2022

Current Implementation Status of National Space Weather Strategy and Action Plan

<u>Objective III</u>: Establish Plans and Procedures for Responding to and Recovering from Space Weather Events

- Exercise Federal response, recovery, and operations plans and procedures for space weather events
  - Needed at Federal, state, and local levels

  e.g. DOT MEF #3: Operate the National Airspace system: Ensure continuous National Airspace System Operations and maintain critical air services and the safety thereof.

LUNCH
12:00 – 1:00 PM ET

1.1: Observational Data and Access (Ground Based)

SWAG Co-Chairs: Jenn Gannon (CPI) and George Ho (JHU APL)

- Anthea Coster (MIT)
- Roger Varney (UCLA)
- Alan Liu (NSF)
- Asti Bhatt (SRI International)

1.1: Observational Data and Access (Ground Based)

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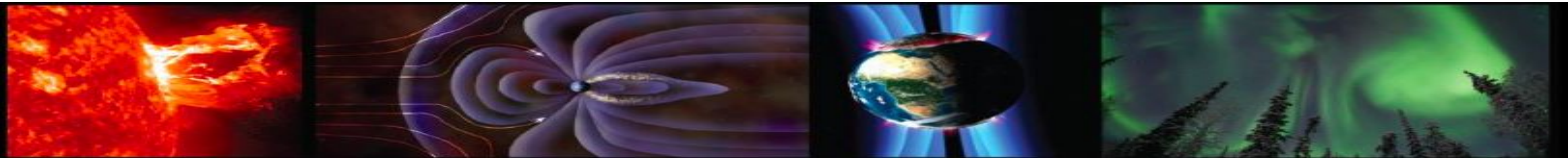
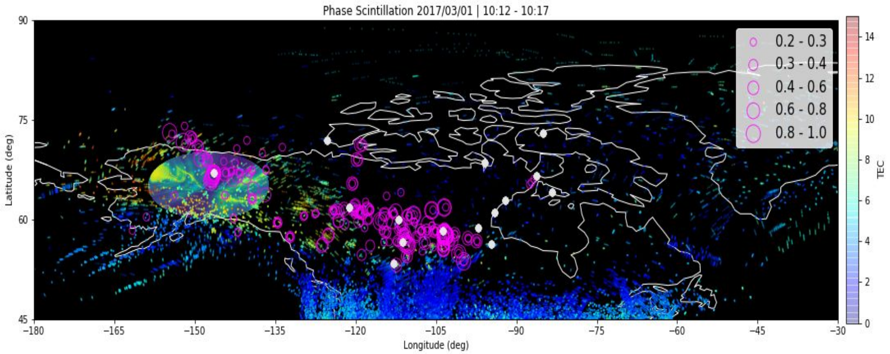


Strengths and Needs of Operational Space Weather Ground-Based Networks

Anthea Coster, MIT Haystack Observatory

There are 351 anomalous phase values.



Ground Based Sensors

- **Magnetometer networks provide Kp, Ap, GIC warnings**
- **Solar Observatories provide F10.7 cm flux**
- **Wang-Sheeley-Arge (WSA)-ENLIL model requires initialization with data from the Global Oscillation Network Group (GONG)**
- **TEC data from GNSS are important for model validation/data assimilation**
- **Incoherent Scatter Radars provide important parameters to calibrate space based measurements**

MIT
HAYSTACK
OBSERVATORY

Space Weather Advisory Group:
Observational Data and Access (Ground-Based)

The National Academies of SCIENCES ENGINEERING MEDICINE

Ground-Based Measurements need to be an ***integral*** part of any SPx Architecture both research and operations

Ground-Based Measurements need an "operational" home; they need support for real-time operations

MIT
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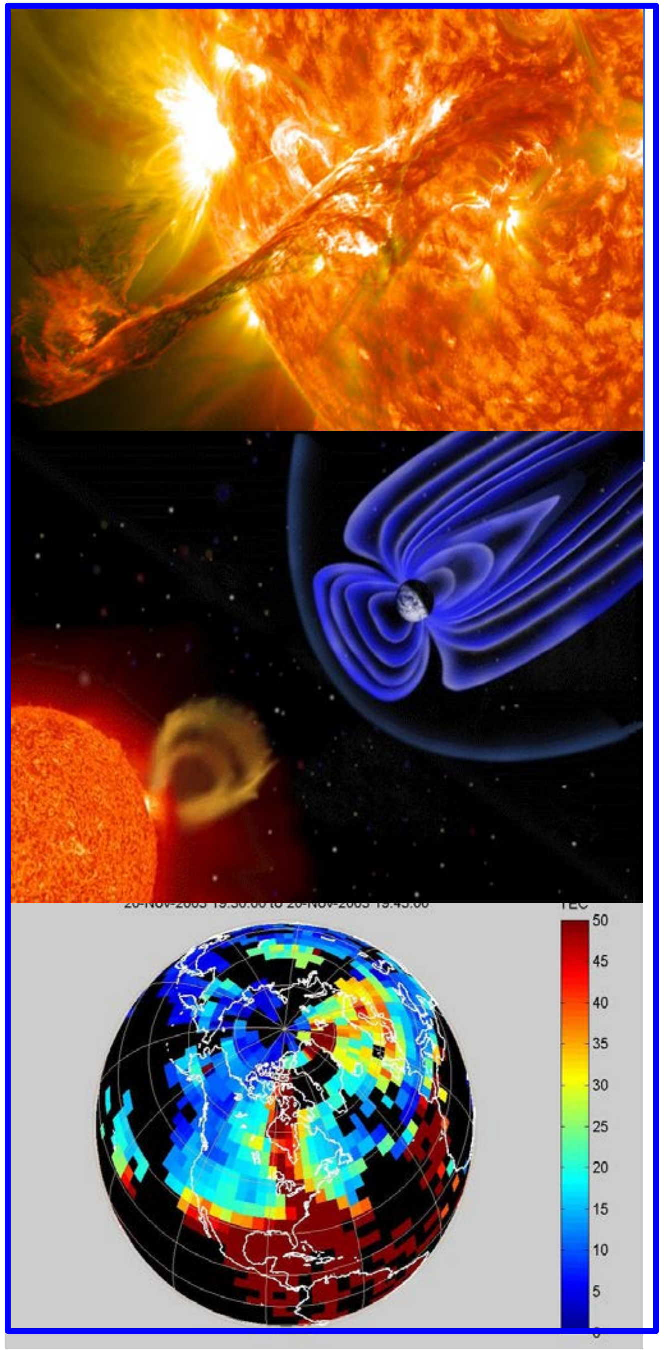
OBSERVATORY



STRENGTHS

- **Cost-effective for space weather monitoring**
- **Provide direct measure of the parameters relevant to effects on critical infrastructure**
- **Distributed networks of sensors yield global physics unattainable with single-point measurements**
- **Ground-based facilities needed to calibrate space-based missions**

NEEDS

- **Most ground-based networks are funded by a mixture of agencies and most are not designed for space weather operations; e.g., the NSF funds science-based networks, not operational networks. Need for specification of which agency or agencies is/are responsible.**
- **Need long-term stable funding for operations.**
- **Support for real-time operations, better communication infrastructure and predictable data quality.**
- **Support for continuous operations to catch space weather events; support for big-data analysis.**
- **A long-term plan for coordinated development and maintenance of ground-based infrastructure.**

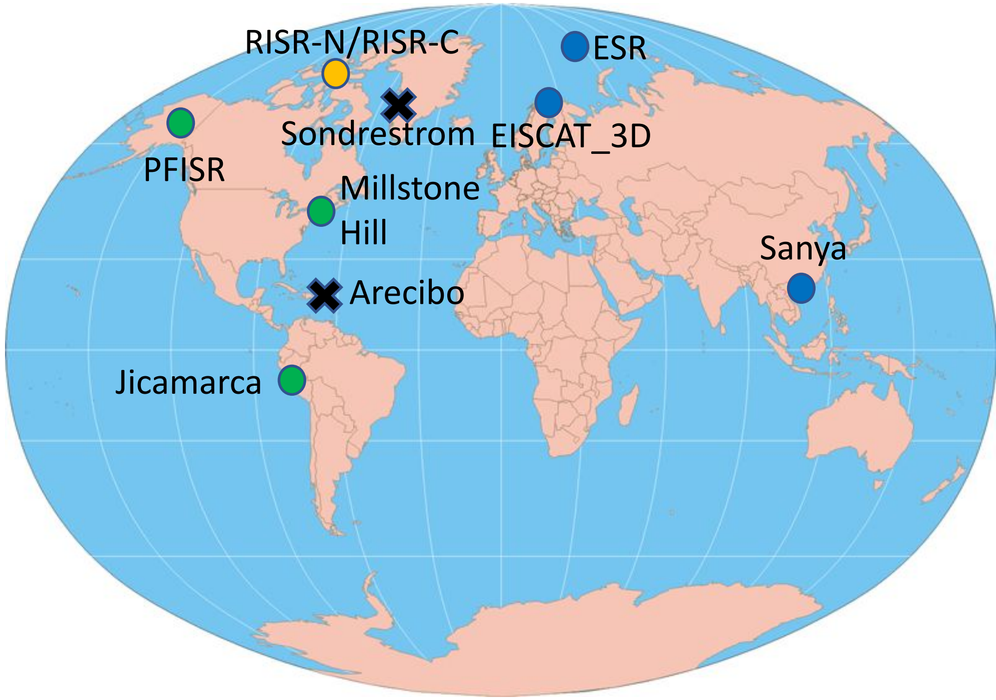
1.1: Observational Data and Access (Ground Based)

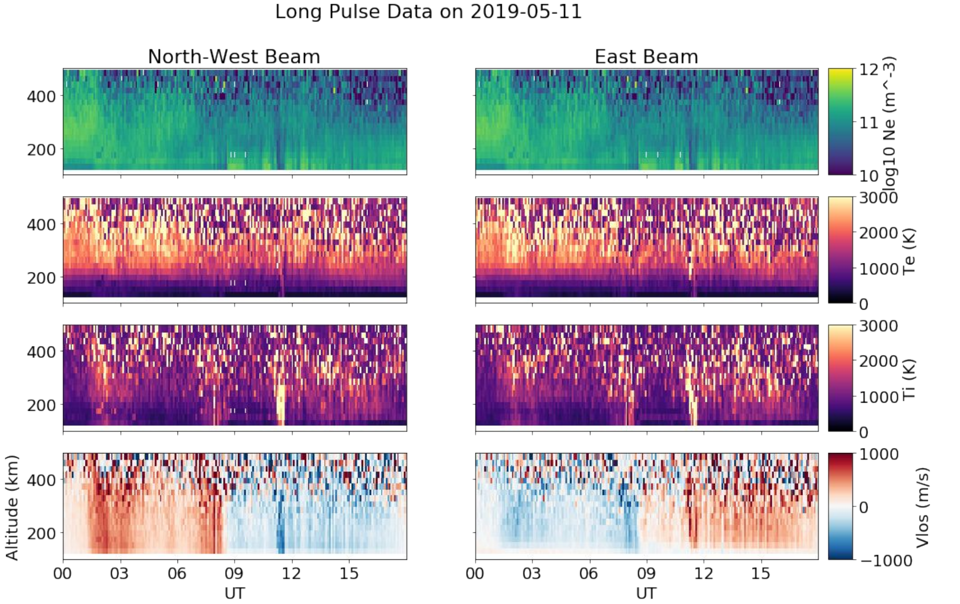
SWAG Co-Chairs: Jenn Gannon (CPI) and George Ho (JHU APL)

- Roger Varney (UCLA)

IS Radar Facilities: Current Status

- Incoherent Scatter (IS) Radars are powerful ground-based systems that can measure complete altitude profiles of important ionospheric parameters (electron density, electron and ion temperatures, ion velocities).
- Facilities can be sorted into three groups:
  - US facilities originally built in the 1960s
    - Jicamarca and Millstone Hill are still operating
    - Arecibo collapsed in 2020
    - Sondrestrom (formerly Chatanika) closed in 2018
  - Advanced modular incoherent scatter radar (AMISR) facilities
    - Poker Flat ISR (PFISR) built in 2006
    - Resolute Bay ISR (RISR-N) built in 2009
    - Designed for a nominal 20-year lifespan
  - International Facilities
    - Sanya Radar in China (operational 2020)
    - EISCAT_3D in Scandinavia (planned to be operational in 2023)
    - EISCAT Svalbard Radar (ESR) in Svalbard, Norway (operational since 1996)
    - RISR-C in Canada (operational since 2015)





Example PFISR data showing altitude-resolved electron density (top), electron and ion temperatures (middle), and ion velocities (bottom)

IS Radar Facilities: Future Recommendations

- Improved long-term planning, interagency coordination, and international cooperation:
  - NSF should develop 10-year plans for ground-based facilities and regularly update them every 5 years. The last planning document was the 2016 portfolio review, and no replacement is anticipated until after the next decadal.
  - Plans for ground-based facilities should be developed in close coordination with NASA and other agencies.
  - Plans for coordinated observations between spacecraft and ground-based observatories should be incorporated into NASA mission planning. The current NASA funding model makes this type of coordination difficult.
  - Establish international agreements to facilitate coordination with highly capable international facilities.
- Improved cyberinfrastructure for ground-based facilities:
  - Create a national facility for ground-based data comparable to the NASA Space Physics Data Facility (SPDF).
  - Create standards for metadata, data quality flags, open-source analysis software distribution, and analysis software revision control. Enable distribution of “analysis-ready data” suitable for machine learning.
  - Provide resources for data management comparable to a mission Science Operations Center (SOC).
  - Provide resources for continued data management of data from closed or decommissioned facilities.
- Improved workforce development and education:
  - Create “guest-investigator” programs for the ground-based facilities to explicitly encourage more researchers to get involved with using the data.
  - Create more frequent opportunities to develop new hardware. Maintaining a workforce with the necessary hardware expertise to upgrade existing facilities or design new ones is very difficult.
  - NSF should capture and retain key technical knowledge that currently only resides in a few institutions.
  - Create opportunities for advanced student training beyond the 1-week annual summer school.

1.1: Observational Data and Access (Ground Based)

SWAG Co-Chairs: Jenn Gannon (CPI) and George Ho (JHU APL)

- Alan Liu (NSF)

Support for Space Weather Research at the National Science Foundation

Alan Liu (in collaboration with Mangala Sharma)

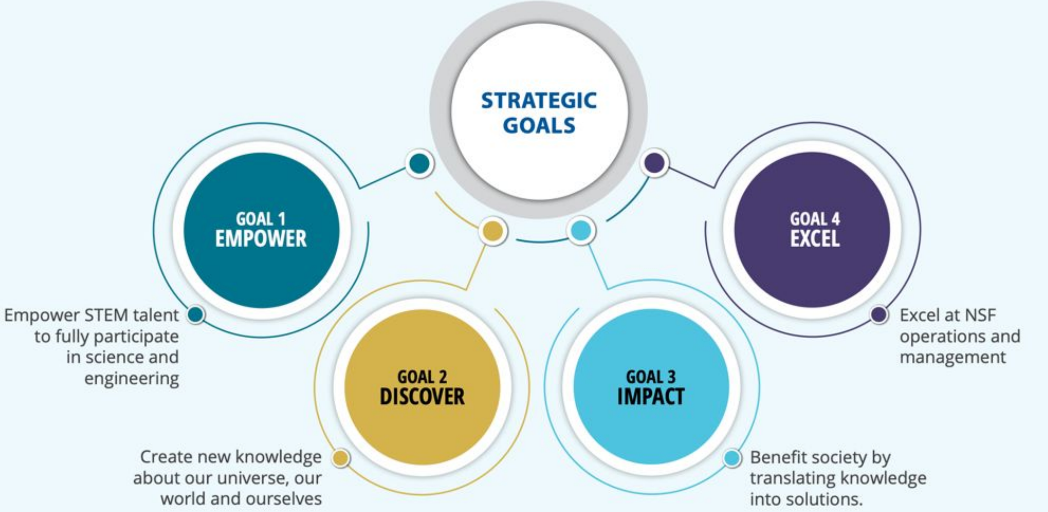
Division of Atmospheric and Geospace Sciences

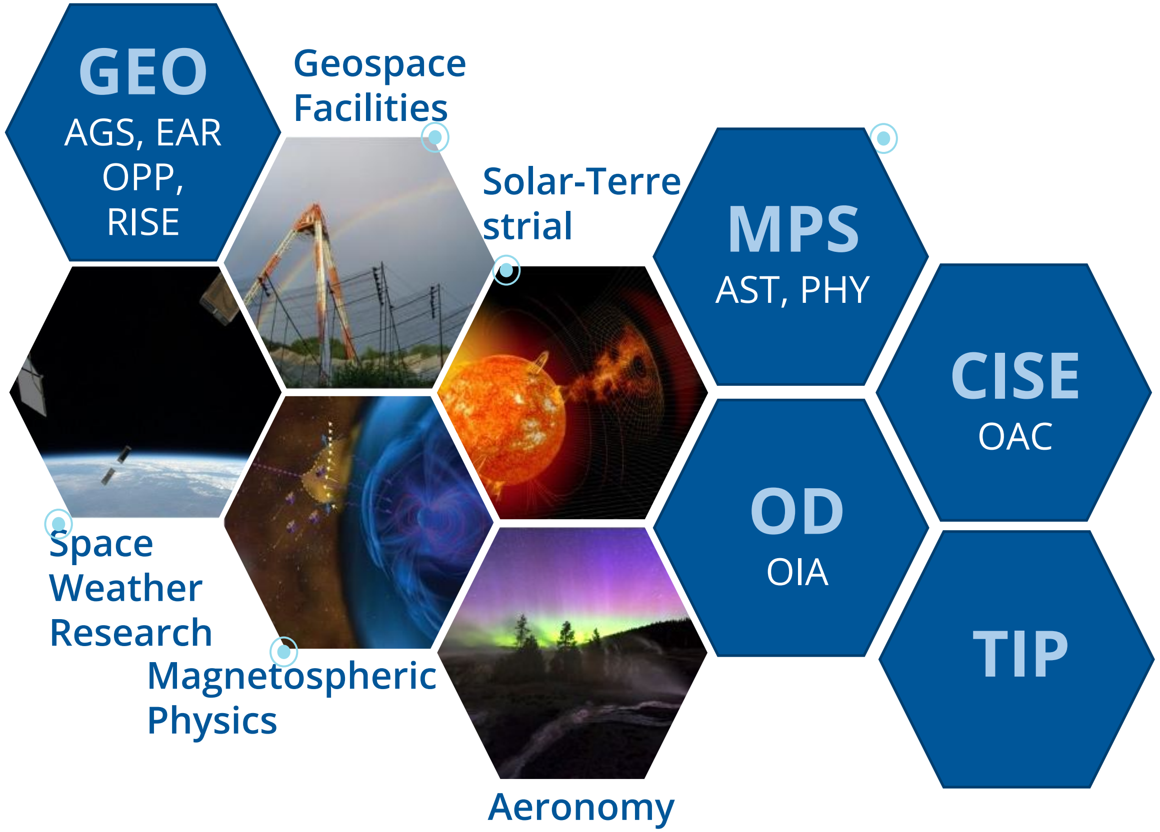
Directorate for Geosciences

THE NSF STATUTORY MISSION

To promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense; and for other purposes.
— From The National Science Foundation Act of 1950 (P.L. 81-507)

NSF strategic plan (2022-26)

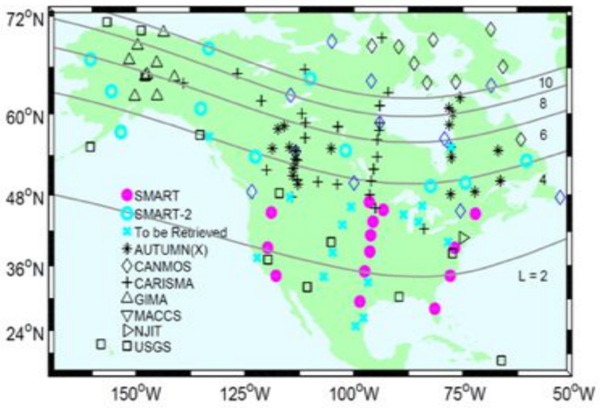




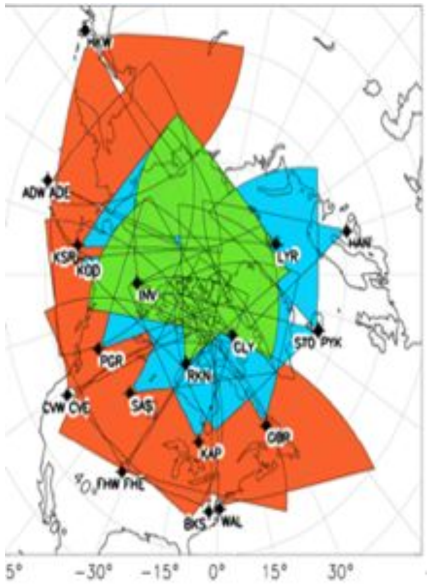
NSF supports fundamental and user-inspired SW research, and R2O2R, but does not directly support SW operations. Funding for modeling, research infrastructure (physical + cyber), and education is through competitive, merit reviewed grant awards, typically for 3-5 years.

NSF supports ground-based solar & geospace observations

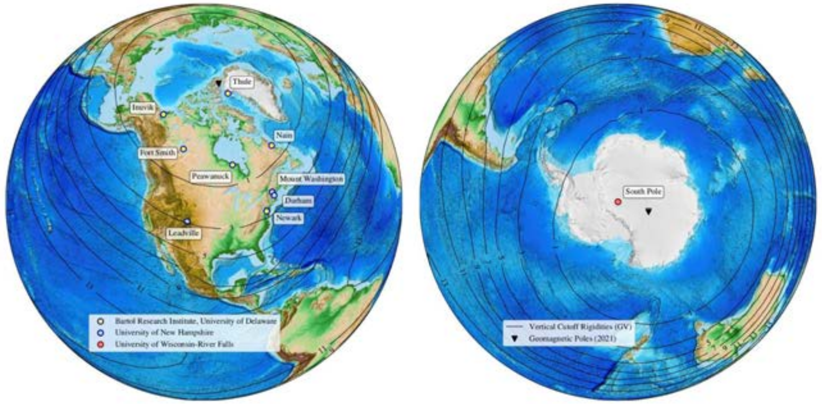
Magnetometers

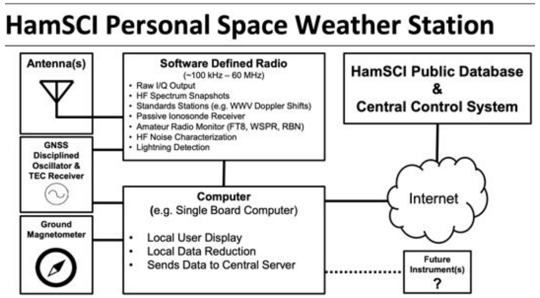


SuperDARN

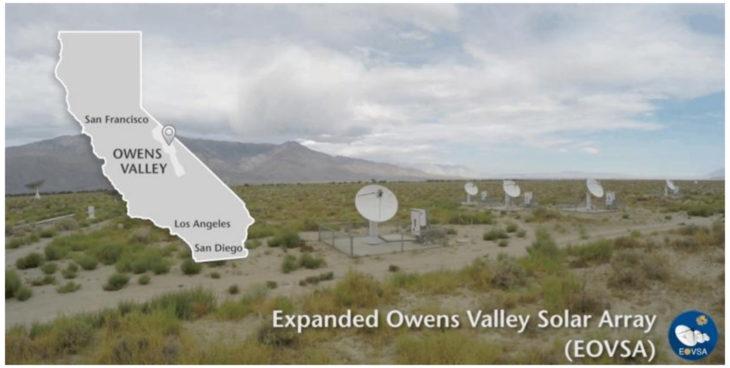


Neutron Monitors





Expanded Owens Valley Solar Array



Global Oscillation Network Group

1.1: Observational Data and Access (Ground Based)

SWAG Co-Chairs: Jenn Gannon (CPI) and George Ho (JHU APL)

- Asti Bhatt (SRI International)

Current status of US-based Optical Networks

- Optical networks of All-sky Imagers (ASIs) provide an accessible way to routinely observe nighttime dynamics of the thermosphere and the ionosphere on a continental scale. The US-based ASI networks observe mid- and sub-auroral latitude thermosphere/ionosphere response to energetic events in the lower atmosphere and the sun. The data are available in near-real time currently.
- Networks of Fabry-Perot Interferometers (FPIs) provide nightly neutral wind measurements, a key component of thermospheric dynamics, but difficult to measure, on a large scale.
- Currently, the US-based optical instruments can be categorized as
  - MANGO network – red and green line airglow imagers and FPIs in a network configuration
  - Boston University imagers – red, green, hydroxyl airglow imagers
  - Standalone instruments on semi-campaign basis
- The MANGO and BU networks operate autonomously, producing continuous data. Higher level data products are available. Some PI involvement needed

A Map of US optical instruments (MANGO and BU) supported by the NSF. The MANGO network is supported through NSF DASI program

Future Needs/Recommendations

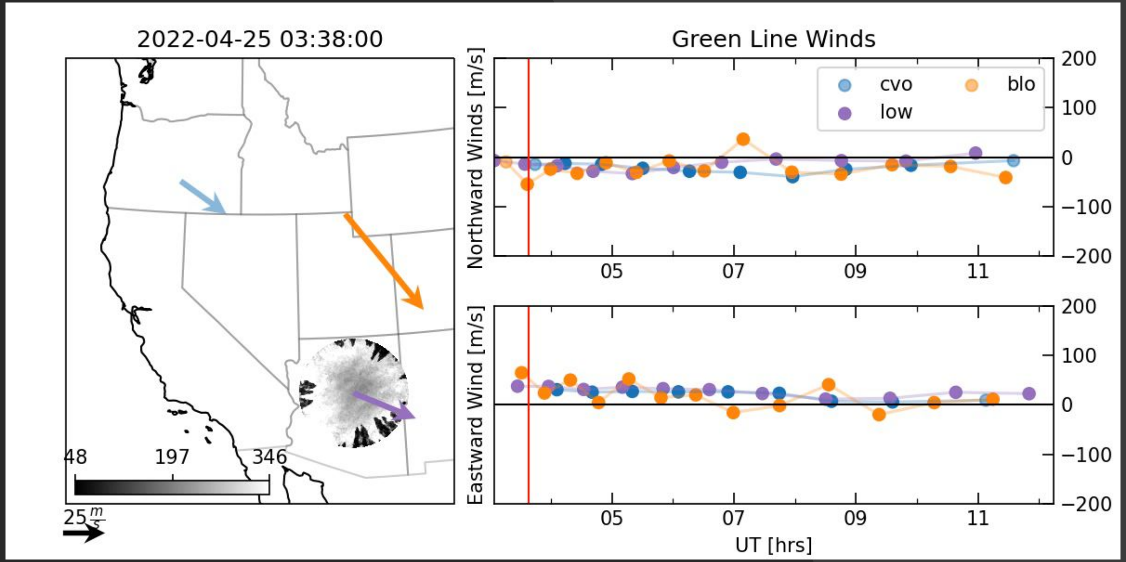
Infrastructure needs:

- The optical networks need to be maintained as networks to be appropriately useful, ie., replacing defunct systems, updating hardware, ensuring uniform performance, supporting site hosts etc.
- Long-term planning at agency-level (NSF/NOAA) for maintaining and growing the established network infrastructure
- Support for long term data storage with backups at a federally supported data center

Data usage for space weather needs:

- Support for data infrastructure development and maintenance, ie., public data access, open-source software, development of higher-level data products
- Creation of guest-investigator programs for wider use of continuously streaming data
- Creation of metadata and data standards in order to curate data effectively and to apply modern data science methods

Combined data product from MANGO green line ASIs and FPIs



Workforce development needs:

- Built-in support for postdocs in ground-based facilities grants dealing with O&M and data production
- Dedicated graduate student support mechanism for universities and facilities to apply for from NSF
- Ensure that technical knowledge on infrastructure is saved at the agency level

1.2: Economic Assessment

SWAG Co-Chairs: Seth Jonas (Lockheed) and Delores Knipp (UC Boulder)

- Jonathan Eastwood (Imperial College)
- Tina Highfill (Bureau of Economic Analysis, DOC)
- Terry Griffin (KSU)

1.2: Economic Assessment

SWAG Co-Chairs: Seth Jonas (Lockheed) and Delores Knipp (UC Boulder)

- Jonathan Eastwood (Imperial College)

Imperial College London

Space Weather Advisory Group (SWAG) Public Meeting 18-20 January 2023
Panel Discussion: Economic Assessments
Wednesday 18 January 2023, 2:00pm EST

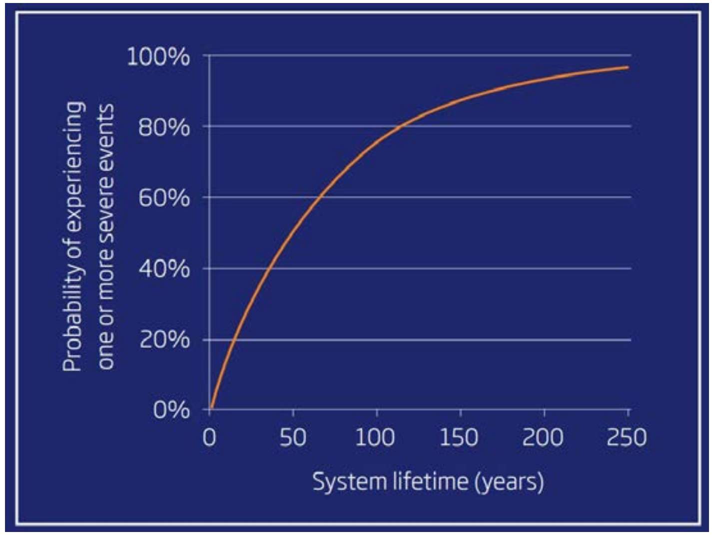
Current status and challenges relating to space weather economic impact

Dr Jonathan P. Eastwood
Reader in Space Physics, and Director of the Space Lab Network of Excellence,
Space and Atmospheric Physics, Blackett Laboratory, Imperial College London, London, UK.

jonathan.eastwood@imperial.ac.uk

Space weather economic impact

Physical driver → Technological/Societal Impact → Economic Impact



‘Carrington level’ event probability (2012 UK Royal Academy of Engineering report, p21)

Science and Technology Facilities Council

Technical Report
RAL-TR-2022-001

Summary of space weather worst-case environments (3rd revised edition)

M Hapgood, M Angling, G Attrill, M Bisi, P Cannon, C Dyer, J Eastwood, S Elvidge, M Gibbs, R Harrison, D Gibbs, R Horne, D Jackson, B Jones, S Machin, C Mitchell, J Preston, J Rees, N Rogers, A Richards, G Routledge, K Ryden, R Tanner, A Thomson, J Wild, M Willis

January 2022

https://epubs.stfc.ac.uk/work/51273983

Oughton+ 2017 (Power, US)
https://doi.org/10.1002/2016SW001491

Oughton+ 2019 (Power, UK)
https://doi.org/10.1111/risa.13229

Eastwood+ 2018 (Power, Europe)
https://doi.org/10.1029/2018SW002003

Den Baumen+ 2014 (Worldwide)
https://doi.org/10.5194/nhess-14-2749-2014

Odenwald+ 2006 (Satellites)
https://doi.org/10.1016/j.asr.2005.10.046

Bolduc 2002 (Power, Quebec)
https://doi.org/10.1016/S1364-6826(02)00128-1

See also review: Eastwood et al., Risk Analysis, 2017 http://dx.doi.org/10.1111/risa.12765

Imperial College London

Space weather economic impact: challenges

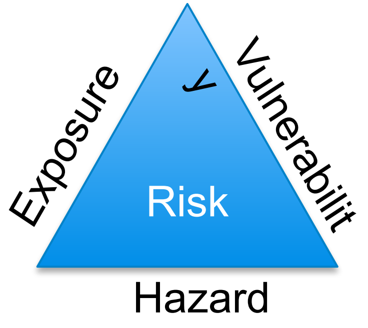
Hazard depends on

a) size and nature of the physical driver
b) forecast quality
c) system resilience

Economic impact depends on

a) spatial-temporal extent of hazard
b) infrastructure vulnerability
c) mitigation strategies
d) other options available to firms and consumers

The space weather risk is constantly evolving



- Challenge: physical driver
  - Very severe impacts have not really happened in the 'modern' era (last 20 years)
  - Each event is unique, so what would actually happen? When and where will space weather effects occur?
- Challenge: technological impact
  - Diverse technological systems (aviation, satellites, comms, PNT) are fused into many aspects of everyday life
  - High potential for interacting system failures: cascading failure modes that are fundamentally difficult to predict
  - Known knowns, known unknowns, unknown unknowns: the biggest risk might be something we have not thought of
- Challenge: economic impact
  - How do we acquire relevant data of sufficient quality to perform meaningful economic impact calculations?
  - Insurance and re-insurance: is the impact due to space weather?

1.2: Economic Assessment

SWAG Co-Chairs: Seth Jonas (Lockheed) and Delores Knipp (UC Boulder)

- Tina Highfill (Bureau of Economic Analysis, DOC)

Measuring the U.S. Space Economy

Space Weather Advisory Group meeting: Economic Assessments

Tina Highfill, PhD

January 18, 2023

Bureau of Economic Analysis
U.S. DEPARTMENT OF COMMERCE

Space economy statistics

Space-related production includes goods and services that:

1. Are used in space, or directly support those used in space
2. Require direct input from space to function, or directly support those that do
3. Are associated with studying space

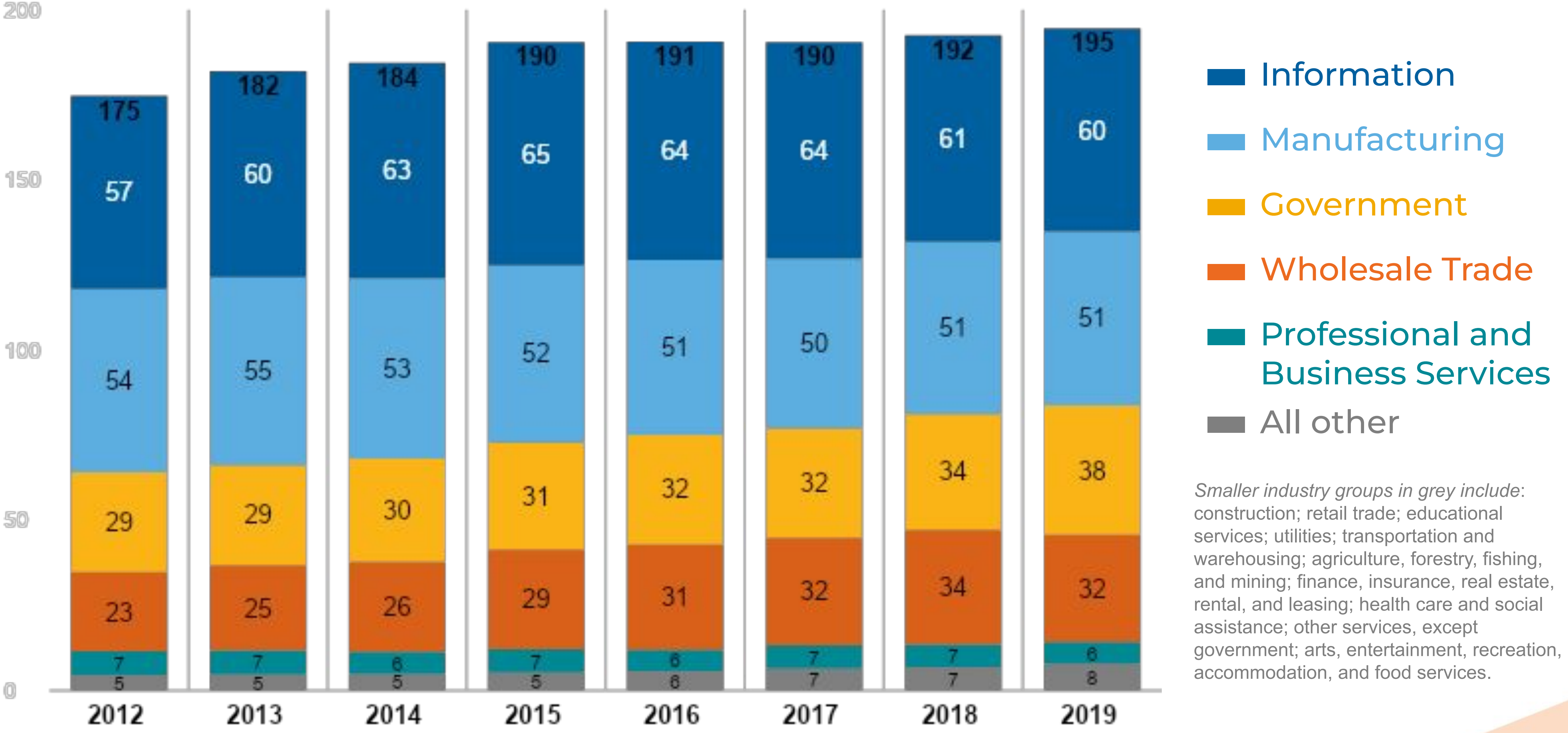
Make Table, Before Redefinitions, 2012
[Millions of Dollars]
Bureau of Economic Analysis

Industry / Commodity		Aircraft manufacturing	Aircraft engine and engine parts manufacturing	Other aircraft parts and auxiliary equipment manufacturing	Guided missile and space vehicle manufacturing
Code	Industry Description	336411	336412	336413	336414
336411	Aircraft manufacturing	100,972	154	3,526	873
336412	Aircraft engine and engine parts manufacturing	269	39,001	421	0
336413	Other aircraft parts and auxiliary equipment manufacturing	3,442	222	29,536	23
336414	Guided missile and space vehicle manufacturing	0			14,957

Source: BEA 2012 supply-use tables https://www.bea.gov/industry/input-output-accounts-data

Space economy gross output by industry, 2012-2019

[Billions of dollars]



Smaller industry groups in grey include: construction; retail trade; educational services; utilities; transportation and warehousing; agriculture, forestry, fishing, and mining; finance, insurance, real estate, rental, and leasing; health care and social assistance; other services, except government; arts, entertainment, recreation, accommodation, and food services.

1.2: Economic Assessment

SWAG Co-Chairs: Seth Jonas (Lockheed) and Delores Knipp (UC Boulder)

- Terry Griffin (KSU)

Economic Assessments

Space Weather Advisory Group (SWAG)
18-20 January 2023

TERRY GRIFFIN, PHD

TWGRIFFIN@KSU.EDU

@SPACEPLOWBOY

AgManager.info

Kansas State University | Agricultural Economics

Basic economics

Farm data use, reuse, and exhaust

Data from sensor	Primary Use	Secondary Use
Yield monitor data	Documenting yields On-farm experiments Splitting crop shares	GxExM analyses
Soil sample data	Fertilizer decisions	Regional compliance Algorithm development
As-applied fertility	On-farm trials Compliance	Regional compliance Algorithm development
	Need 1 field	Need all fields

Contact information

Terry Griffin, Ph.D.

twgriffin@ksu.edu

@SpacePlowboy

BREAK
3:00 – 3:30 PM ET

Committee Discussion

- **Issues and recommendations from today's talks**
- **Preview of tomorrow**

Committee Discussion

- **Draft economic assessment recommendations**

Committee Discussion

- **Draft recommendations from morning sessions**

ADJOURN DAY 1

Day 2 begins at 9am ET, Thursday, 19 Jan 2023

DAY 2

Welcome!

- In accordance with section 60601 of the PROSWIFT Act - NOAA established the SWAG to advise the White House SWORM Interagency Subcommittee

- All 15 non-governmental representatives of the SWAG, were appointed by the SWORM Subcommittee with 3-year terms beginning on October 1, 2021

- Each SWAG member here today serves as a representative member to provide stakeholder advice reflecting the views of the entity or interest group they are representing. The PROSWIFT Act directs SWAG members to receive advice from the academic community, the commercial space weather sector, and space weather end users that will inform the interests and work of the SWORM

Roll Call

SWAG Nongovernmental End-User Representatives

Tamara Dickinson, SWAG Chair
Science Matters Consulting

Mark Olson
North American Electric Reliability Corporation

Michael Stills
United Airlines (retired)

Craig Fugate
One Concern

Rebecca Bishop
Aerospace Corp.

SWAG Commercial Sector Representatives

Jennifer Gannon
Computational Physics, Inc.

Conrad Lautenbacher
GeoOptics, Inc.

Seth Jonas
Lockheed Martin

Kent Tobiska
Space Environment Technologies

Nicole Duncan
Ball Aerospace

SWAG Academic Community Representatives

Tamas Gombosi
University of Michigan, Ann Arbor

Delores Knipp
University of Colorado, Boulder

Scott McIntosh
National Centers for Atmospheric Research

Heather Elliott
Southwest Research Institute

George Ho
Johns Hopkins University Applied Physics Laboratory

Recap of Day 1

- Welcome and Recap of Meeting 3
- Progress Since Meeting 3
- NOAA Administrator Remarks
- SWORM Co-Chair remarks
- Roundtable and Council Updates
- Current Status of Implementing the National Space Weather Strategy and Action Plan
- Session 1.1 Observational Data and Access (Ground Based)
- Session 1.2 Economic Assessment
- Committee Discussion
- Closing Remarks

Agenda Day 2

- Welcome and Recap of Day 1
- Session 2.1: *Observational Data, Access, and Infrastructure in Space*
- **Break 10:40 - 11:00 AM ET**
- Session 2.2: *Benchmarks, Metrics, and Scales*
- Lunch 11:45 - 12:45 PM ET
- Session 2.3: *Data Infrastructure and Methods*
- Session 2.4: *Evolving Infrastructure Systems and Services*
- Break 3:00 - 3:30 PM ET

Agenda Day 2 (continued)

- Session 2.5: *Industry and Government collaboration, Coordination, Outreach, and Communications in Space Weather*
- Public Comments
- Committee Discussion
- Closing Remarks
- Adjourn Day 2

Agenda Day 3

- Welcome and Recap of Day 2
- Committee Discussion
  - Recommendations
  - Writing Assignments
  - Next Steps and Timeline
- Closing Remarks
- Adjourn the Meeting

2.1: Observational Data, Access and Infrastructure in Space

- **Recommendations related to space-based observations, data & infrastructure in the 2019 SWx Strategy and Action Plan**
  - **Objective 1.6:** Identify and prioritize R&D necessary to enhance the security and resilience of critical functions and national security assets to the effects of space weather.
  - **Objective 2.3:** Support and coordinate opportunities for fundamental research in heliophysics and geospace sciences.
  - **Objective 2.5:** Enhance current space weather models and develop improved modeling techniques for space weather.
  - **Objective 2.6:** Identify and release, as appropriate, new or previously underutilized data sets.
  - **Objective 2.11:** Develop and refine situational awareness capabilities.
  - **Objective 3.3:** Facilitate information sharing to inform and enhance the operation and restoration of critical infrastructure at greatest risk to the effects of space weather.

- **Solicit input about space weather relevant**
  - Observational data needs
  - Novel and systematic approaches to acquiring observational data
  - Data accessibility challenges from past, current and future missions
  - How a comprehensive observational infrastructure could be deployed in space

2.1: Observational Data, Access and Infrastructure in Space

SWAG Co-Chairs: Nicole Duncan (Ball Aerospace) and Heather Elliott (SWRI)

- Sean Elvidge
  - Emerging role of OSSES in improving our understanding of space weather.
- Sarah Gibson
  - Current state and future need of solar observing networks for space weather research and applications.
- Lisa Upton
  - Need for multi-point measurements for space weather research and operation.
  - Highlights from AGU 2022 session “SH42B: Heliophysics Research Outlook: The Need for Multi-viewpoint Observations”
- Slava Merkin
  - Importance of a systems approach to address mesoscale science topics in support of space weather missions and products.
  - Heliophysics 2050 white paper “Mesoscale dynamics - the key to unlocking the universal physics of multiscale feedback.”
- Neal Nickles
  - Space weather data needs and accessibility for anomaly attribution.
  - Data needs for technical planning of space hardware and conducting in-space operations.

2.1: Observational Data, Access and Infrastructure in Space

SWAG Co-Chairs: Nicole Duncan (Ball Aerospace) and Heather Elliott (SWRI)

- Sean Elvidge (University of Birmingham)

UNIVERSITY OF BIRMINGHAM

SERENE SPACE ENVIRONMENT

Observational Data, Access, and Infrastructure in Space

Dr. Sean Elvidge

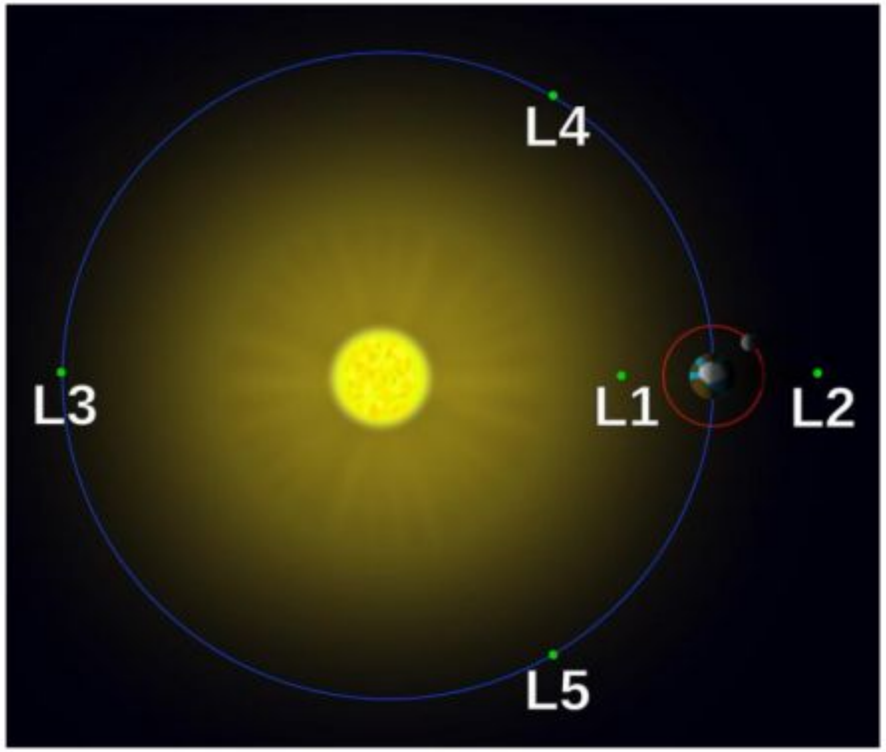
Associate Professor of Space Environment,
Head of Space Environment Research,
University of Birmingham, UK

Space Weather Advisory Group - Meeting 4
January 19th 2023

Space Weather Data Needs & Access

- Ask five space weather scientists about their data needs to improve forecasting and you'll get (at least) 15 suggestions. Including:
    - (Near) real-time, high-resolution measurements of the solar wind density, temperature, magnetic and electric fields,
    - Measurements of the Solar corona and inner heliosphere,
    - "L5" Observations,
    - Thermosphere (species) density and winds.

- "Operational" access to data requires:
    - Long-term storage,
    - Good maintenance,
    - Redundancy
    - Documentation



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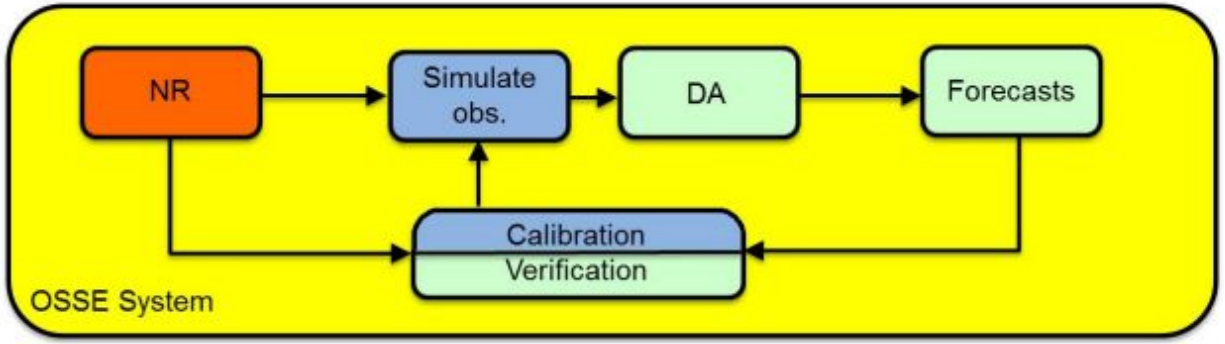
SERENE SPACE ENVIRONMENT

Observing System Simulation Experiment (OSSE)

- An OSSE is a modelling experiment used to evaluate the value of new datasets



Hoffman & Atlas (2016)

- Whilst they are used in Space Weather (e.g. OSSE session at AGU 2022) they are "ad-hoc" often developed by the dataset proposer themselves – who are often not modelling experts
  - Building such a system can be complex to design and expensive to run, data are likely not independent and consequently they tend to over-estimate the benefits of a new dataset
- Support for independent OSSE systems, open to the community, should be developed by modelling experts allowing the fusion of the potential new observations with a wide range of existing datasets
  - Common-tools can help Agencies when evaluating the cost-benefit analysis of new experiments

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SERENE SPACE ENVIRONMENT

2.1: Observational Data, Access and Infrastructure in Space

SWAG Co-Chairs: Nicole Duncan (Ball Aerospace) and Heather Elliott (SWRI)

- Sarah Gibson (UCAR)

Space Wx and the Whole Heliosphere

Why we need a systematic approach to Heliophysics observations and modeling:

- Current operational requirements are based on knowledge gleaned primarily from single-discipline studies
- Going beyond nowcasting requires a clear understanding of couplings between multiple regimes
- Ultimately, we need a comprehensive set of observations/models optimized to fill space and time

How a comprehensive infrastructure could be envisioned and deployed:

Space-based observations

Why we need them for Space Wx:
- Ability to observe short wavelengths, *in-situ*
- Ability to observe from vantages off Sun-Earth line, looking down on Earth
- ***Continuous data stream***

What we need more of in future:
- Instrument miniaturization and standardization
- New vantages (polar, L5, upstream sentinels)

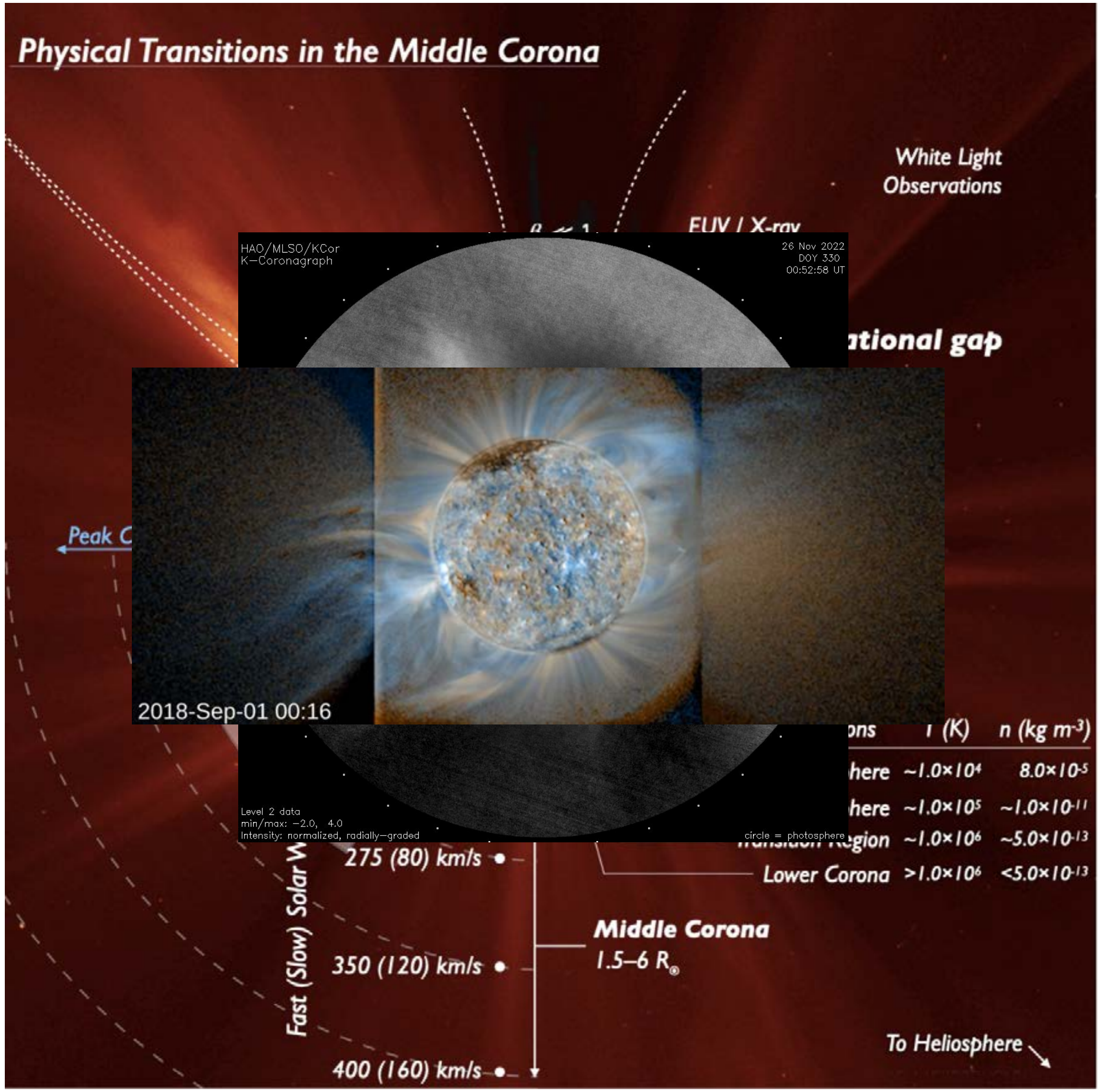
Ground-based observations

Why we need them for Space Wx:
- Ability to observe regions/spectral ranges difficult/expensive from space
- Ability to upgrade easily
- ***Data latency and high time cadence***

What we need more of in future:
- Global coverage (latitude, longitude)
- Next-generation observations

Tools for archiving, accessing, and utilizing observations across the system, and for globally interpreting them

Filling Gaps with Solar Observing Networks

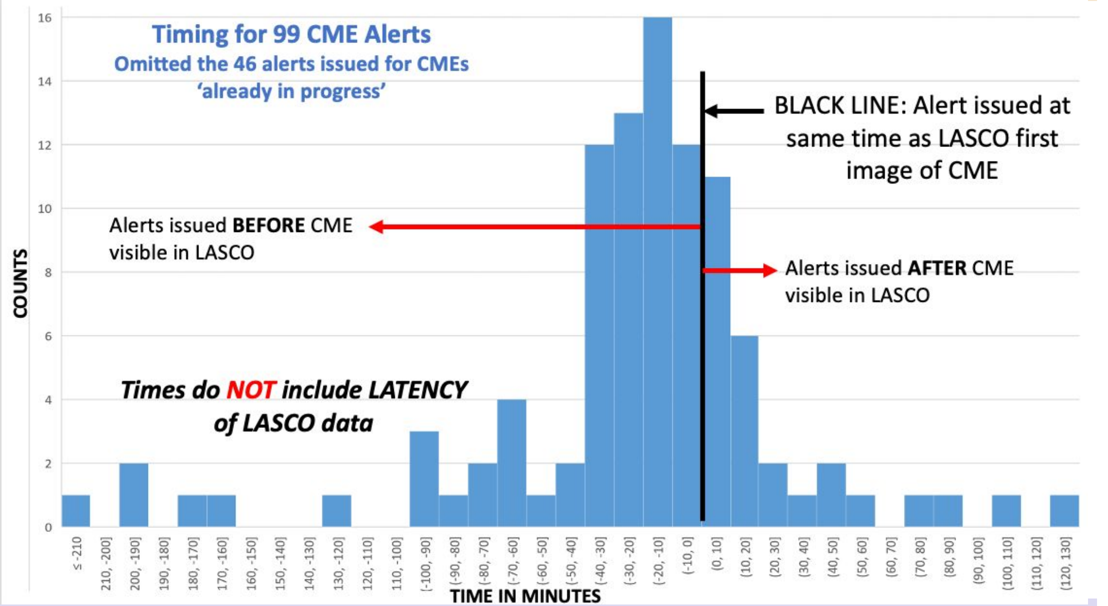


West et al., 2023, in preparation

How to fill the middle corona gap (WP: 1, 2, 3, 4, 5, 6, 7, 8):

EUV imagers in space
- Current: SDO/AIA, STEREO/EUVI, GOES/SUVI
- --> wide FOV (SUVI extended imaging mode)
- --> miniaturization/simplification (SunCET Cubesat)

K-Cor:
CME early warning – **2.5 hours before LASCO (Key for SEPs)**



Ground-based coronagraphs:
- Current: COSMO K-Cor; UCoMP V/IR specpol
- □ longitudinally distributed networks (NG-GONG)
- □ global coronal magnetic measurements (COSMO)

2.1: Observational Data, Access and Infrastructure in Space

SWAG Co-Chairs: Nicole Duncan (Ball Aerospace) and Heather Elliott (SWRI)

- Lisa Upton (SWRI)

Heliophysics Research Outlook: The Need for Multi-viewpoint Observations

STEREO-A and B, The Solar Orbiter, and Parker Solar Probe have demonstrated the power that observations from new vantages provide for SWx research and operations.

The missions: Firefly, Solaris+, COMPLETE, MOST, Seven Sisters, MAKOS

- Firefly: holistic observational approach that extends from the Sun's interior to the photosphere, through the corona, and into the solar wind simultaneously with multiple spacecraft at multiple vantage points.
- Solaris+: images of the Sun's poles from 75° latitude, providing new insight into the workings of the solar dynamo and the solar cycle, and new view of the corona, coronal dynamics and CME eruption from above.
- COMPLETE: comprehensive measurements of the 3D low- and middle-coronal magnetic field and simultaneous 3D energy-release diagnostics from large eruptions down to small-scale processes.
- MOST: imagery and time-series data of the Sun to understand the magnetic coupling between the solar interior and the extended atmosphere
- Seven Sisters: 1) Measure Longitudinal Structure of the Coronal Mass Ejections, 2) Enable Advanced Prediction of IMF Orientation at Earth, 3) Determine Particle Energization Processes in Solar Wind Structures.
- MAKOS: observation of both the terrestrial bow shock as well as interplanetary shocks in the solar wind.

Multi-spacecraft Pathfinder & Flagship Missions with Both Remote Sensing and In Situ Observations

Needed to provide actionable forecasts of space weather events and the solar cycle:

- Doppler & Coronal Magnetographs (along with Spectroscopic Imaging)
- View of sunspot active regions and filaments throughout their entire lifecycles
- Accurate imaging of the magnetic field of the Sun's poles (direct LOS at high lats)
- Observations of coronal dynamics from multiple new perspectives
- Measurement of the solar wind at multiple points, including high latitudes
- Improved Communications Network

We have to get away from the SEL – to see the far-side!!
We have to get out of the ecliptic – to see the poles!!!

2.1: Observational Data, Access and Infrastructure in Space

SWAG Co-Chairs: Nicole Duncan (Ball Aerospace) and Heather Elliott (SWRI)

- Slava Merkin (APL)

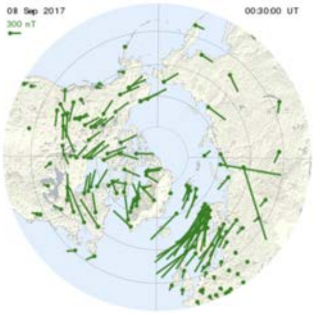
Space weather data requirements from modeling perspective

Getting used to the idea of data-model fusion (gray-box modeling)

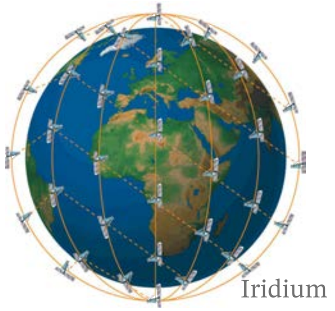
Solving challenges of data assimilation in global geospace:

- Use spacecraft constellations and remote-sensing (e.g., imaging)
- Leverage better near-Earth coverage
- Leverage historical data
- Use all available data to:
  - Rectify model incompleteness (i.e., supply missing physics)
  - Develop data ingestion/assimilation methods that nudge models by supplying missing physics (i.e., **gray-box models**)
- All of the above entails using and developing DM/ML methods

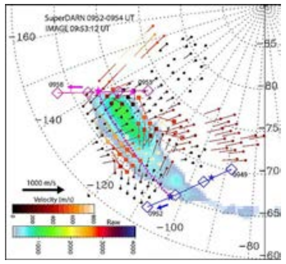
SuperMAG



AMPERE



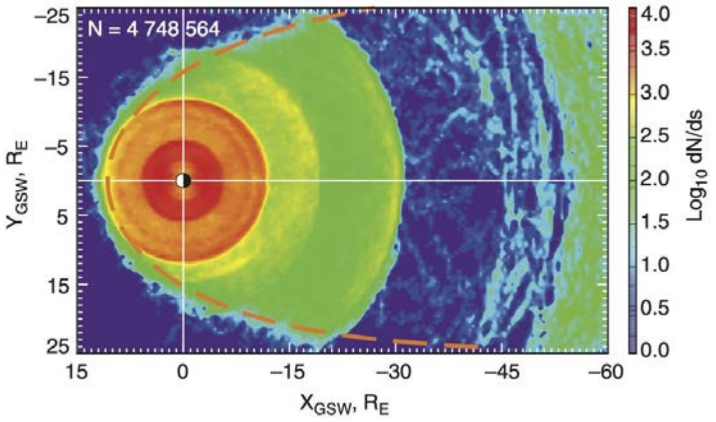
Iridium Communications Inc.



SuperDARN+
DMSP+
IMAGE

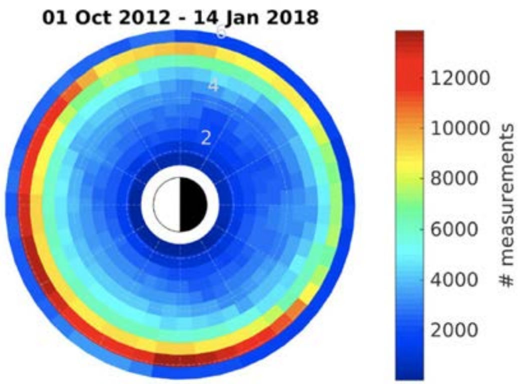
Zou et al. (2009)
10.1029/2008JA013449

Historical magnetometer data (Tsyganenko et al. 2021)



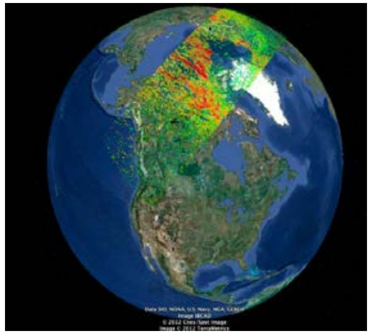
10.1002/9781119815624.ch39

Historical Van Allen Probes data (Wang et al. 2019)



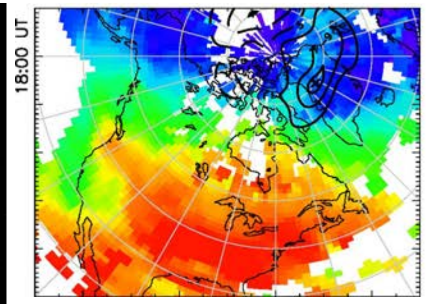
10.1029/2018JA026183

DMSP/SUSSI



sussi.jhuapl.edu

GPS TEC

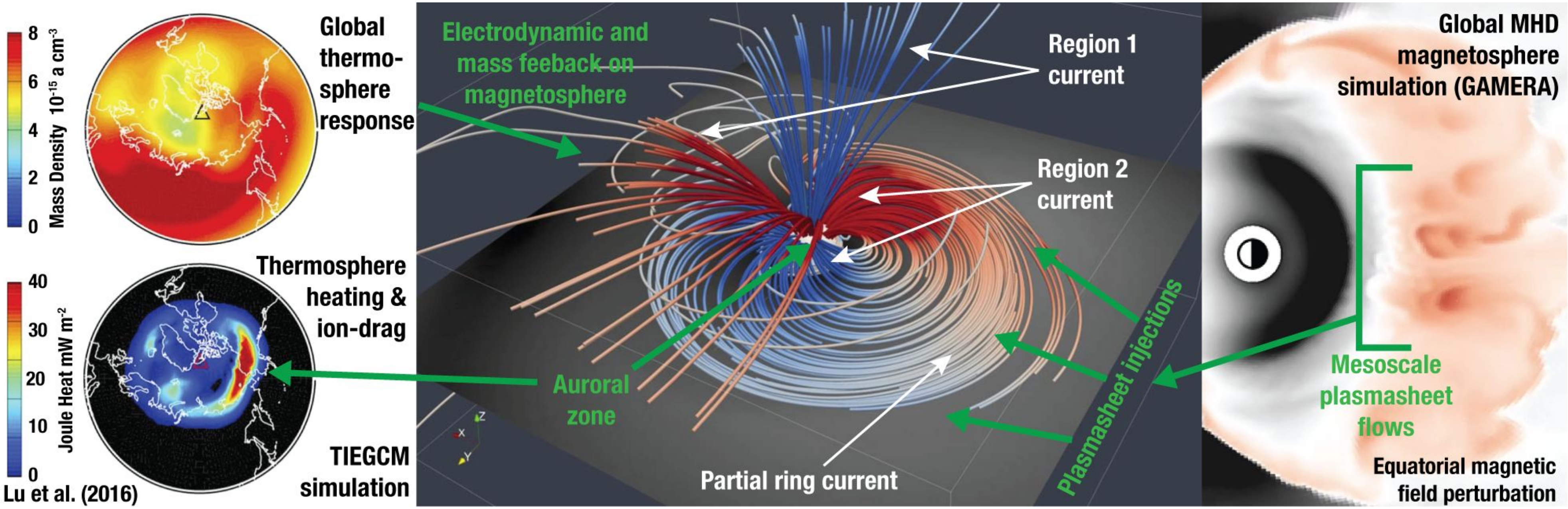


vt.superdarn.org

The need for mesoscale-resolving observations

Mesoscale processes are ubiquitous in geospace but are currently poorly sampled or understood

Mesoscale processes may have global-scale consequences:



Example space weather impacts of mesoscale processes in geospace:

- BBF (bursty bulk flows) pumping of the ring current and radiation belts
- Mesoscale (≳100s km) energy deposition in the ionosphere/thermosphere
- GIC generation by localized ionospheric currents

2.1: Observational Data, Access and Infrastructure in Space

SWAG Co-Chairs: Nicole Duncan (Ball Aerospace) and Heather Elliott (SWRI)

- Neal Nickles (Ball Aerospace)

Unmanned Space-craft User Assessment and Needs

Neal Nickles, Ph.D. Technical Fellow

Radiation and Charging System Assurance

January 19, 2023

GO BEYOND WITH BALL.®

UNMANNED SPACECRAFT (SC) USER NEEDS AND SWx MONITORING

- SC need alerts, worse-case scenarios and historical/predictive climatology over forecasting
- Unmet needs for designing for/attributing dose, single event and space charging effects
  - GEO (or L1) heavy ion flux or at least Linear Energy Transfer (LET) monitor
  - Worst-case surface charging modeling parameters from plasma and 10-50 keV electrons for HEO (Van Allen Probe) and MEO (GPS) and LEO (was DMSP)
  - Continued 850 km LEO 2-MeV electron flux index (after NOAA-19). Enables VERB code for RADSAT charging tool for non-GEO L-shells (MEO, HEO, LEO)
  - Continued 850 km LEO 10-300 MeV trapped proton monitoring (after NOAA-19)
  - Auroral imagery and continued ground-based neutron monitoring network (pinpoint events)
  - Proliferated dosimetry on all government space missions
  - MEO and HEO (GTO) coverage, not just LEO and GEO and L1

Planned observations should be ready to continue full suite of monitoring across belts and catch worst-case events

USER SWx INSTRUMENTATION AND IMPROVED DATA ACCESSIBILITY

- Recommended example instruments that balance user needs vs. scientific modeling research
  - Cosmic Ray Telescope or LET monitor - Improve on attempted GOES-R instrument and CRaTER on LRO. Model after Univ. Chicago Cosmic Ray Telescope on IMP-8.
  - Instruments: VBP ECT and RPS (in p+ belt), thermal plasma sensor, and GCR monitor (in GEO or L1)
  - Distributed, government-funded SWx monitoring – JPL EC RadMon, RADFETs, CEASE-3 or EPC-Lite
- Recommend GUI interface for alert/historical data and centralized US portal for users
  - Data accessibility and centralized GUI interface enables newer SWx effects engineers (smallsats and proliferated SC) to provide robust and inexpensive space systems to the greater user community
  - SWx historical data (need 30 years) is difficult to access (reinstate GUI user interface like SPIDR)
    - NGDC decommissioned the SPIDR (Space Physics Interactive Data Resource) website in 2016
  - SWPC stopped useful list of CME in 2017 (https://www.ngdc.noaa.gov/stp/satellite/goes/doc/SPE.txt)
  - SWPC should compile particle energy spectra at peak of index alert events (for detailed SC analysis)
  - US government needs one central website portal to all user data needs (alerts/historical/predictive)
    - Consider NASE (NASA Applied Space Environments) https://www.nasa.gov starting again MSFC SEE website

SC users could benefit from easily accessible space weather data for quick anomaly resolution to re-start missions

2.1 - Discussion

2.1 - Discussion Questions

- How does National interest in the Moon and Mars effect space weather observational needs, research topics and in-space infrastructure?
- Coronagraph measurements are called out in legislation as critical infrastructure, but what observations are already or are becoming critical for space weather purposes but aren't codified into legislation?
- What new observations are critical for improving the accuracy of space weather forecasts?
- What new vantage points are necessary for improving the accuracy of space weather forecasts and/or meeting future space weather needs?
- How would a satellite operator use an anomaly database and is this a priority?
- How could Research-to-Operations be incorporated into Mission Design and Development?

BREAK
10:40 – 11:00 AM ET

Session 2.2 Benchmarks, Metrics, and Scales

SWAG Co-Chairs: Kent Tobiska (SET), Craig Fugate (former FEMA), and Mike Stills (retired UA)

Discussion highlights

- **Objective**: capture concepts on benchmarks, metrics, scales that can evolve into recommendations from SWAG to SWORM
- **Method**: Consider benchmarking, metrics, and scales in the context of space weather domains vs. societal sectors
- **Tentpoles**: How best to manage space weather risks from precedencies (benchmarks), comparisons (metrics), and advisories (scales)
    - What are the commercial, academic, agency, and international collaborative approaches towards benchmarks, metrics, scales?
    - Are the most current, validated data being used to inform benchmarks, metrics, scales?
    - Where, if any, are there gaps in approaches to benchmarks, metrics, scales?
    - Can benchmarks, metrics, scales be prioritized?

Roadmap for discussion – see Note* at end

Space weather domain Societal sector	Induced geo-electric fields	Ionizing Radiation	Ionospheric disturbance	Solar Radio Bursts	Upper Atmosphere Expansion
Aviation		2	2		
Emergency Management					
GNSS					
Human Space Flight					
Electric Power Grid					
SSA/STM-C					
Research					
National Security					
RF Applications					
Satellite					

*Note number at end of this document is referenced in the matrix

Session 2.2 Benchmarks, Metrics, and Scales

SWAG Co-Chairs: Kent Tobiska (SET), Craig Fugate (former FEMA), and Mike Stills (retired UA)

- Steve Morley (Los Alamos National Laboratory)
- David Boteler (Natural Resources Canada)
- Richard Horne (British Antarctic Survey)

Session 2.2 Benchmarks, Metrics, and Scales

SWAG Co-Chairs: Kent Tobiska (SET), Craig Fugate (former FEMA), and Mike Stills (retired UA)

- Steve Morley (Los Alamos National Laboratory)

Los Alamos
NATIONAL LABORATORY

Comments to Space Weather Advisory Group Public Meeting

19 January 2023

Dr. Steven K. Morley
Space Science and Applications (ISR-1), Intelligence and Space Research Division

Current Geoelectric Hazard Benchmarks are Limited

- SWORM presented geoelectric hazard maps for geoelectric field benchmarks
  - Hazard maps can be useful for informing probabilistic models of hazardous events
  - Spatial map of 1-in-100-year geoelectric field does not reflect spatial structuring of individual events
  - A map showing 1-in-100-year magnitudes does not reflect any possible realization of a 1-in-100-year event, and is prone to misinterpretation as a benchmark event
  - Power systems modeling requires spatiotemporal time series, which hazard maps do not provide

- TPL-007 reliability standard includes a benchmark time series
  - Scaled to nominal 1-in-100-year peak geoelectric field magnitude, does not account for uncertainty in return period
  - Single realization of benchmark event does not account for variability in spectral/temporal characteristics of geomagnetic disturbance (GMD) events
  - 1D time series does not reflect spatial structuring of GMD events

Probabilistic Hazard Analysis is Required

- Using a single reference event is not best practice for natural hazards
  - E.g., a database of event spectra is used for probabilistic seismic hazard analysis[1]
  - Probabilistic models and Monte Carlo simulations are used for impacts of other natural hazards[2]
  - Sparse data with limited history means that uncertainties on event amplitudes and likelihoods can be large

- Probabilistic statistical models[2,3] or ensembles of simulated scenarios are required to reliably assess geoelectric hazard
  - Event time-of-day impacts likely outcome due to different spectra, likelihood of localized enhancements, and local time of infrastructure[3]
  - Temporal evolution of given events is important for outcomes such as transformer hotspot heating[4], so simple uncertainties on drivers are insufficient
  - Interaction of spatiotemporal evolution with transmission system load is important for outcomes such as voltage collapse[5], again suggesting a Monte Carlo approach

References: 1 – NUREG/CR-6728; 2 – DOE-STD-1020-2016, DOE-HDBK-1220-2017; 3 – EPRI, 3002017900, 2020; 4 – Marti, 2013 (doi: 10.1109/TPWRD.2012.2224674); 5 – Mate et al., 2021 (doi: 10.48550/arXiv.2108.06585).

Session 2.2 Benchmarks, Metrics, and Scales

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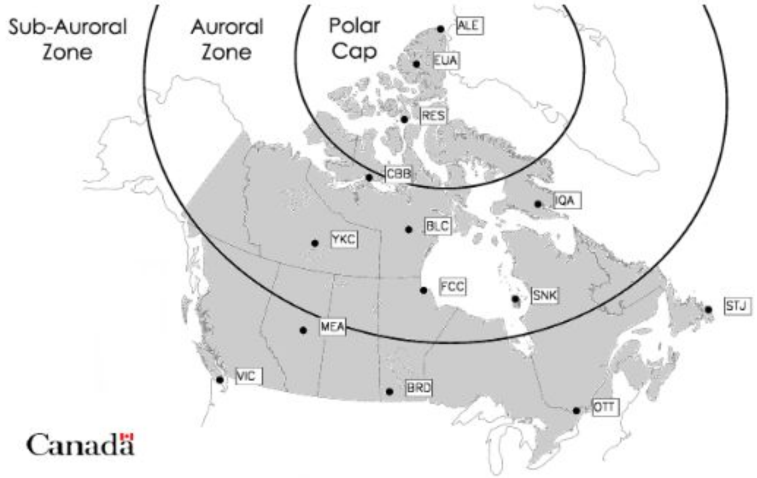
- David Boteler (Natural Resources Canada)

NRCan Geomagnetic Activity Levels

Short Term Hourly Range Activity Levels (nT)					
Zone	Quiet	Unsettled	Active	Stormy	Major Storm
Polar Cap	0 - 50	50 - 100	100 - 180	180 - 600	600+
Auroral Zone	0 - 90	90 - 170	170 - 300	300 - 1000	1000+
Sub-Auroral Zone	0 - 30	30 - 50	50 - 90	90 - 300	300+



Quiet	K3	Unsettled	K4	Active	K5	Stormy	K7+Major Storm

Examples of Impact Statements

Power Systems: Geomagnetically induced currents may cause some effects on system operations in the auroral & sub-auroral zones.

HF Radio Systems: HF radio system degradation event possible with the potential to strongly impact HF radio systems in the polar cap zone.

GNSS: GNSS degradation event in progress with the potential to impact the accuracy of GNSS positioning and/or timing. Further periodic GNSS degradation possible at high latitudes.

Design of Space Weather Scales

Choose the domain

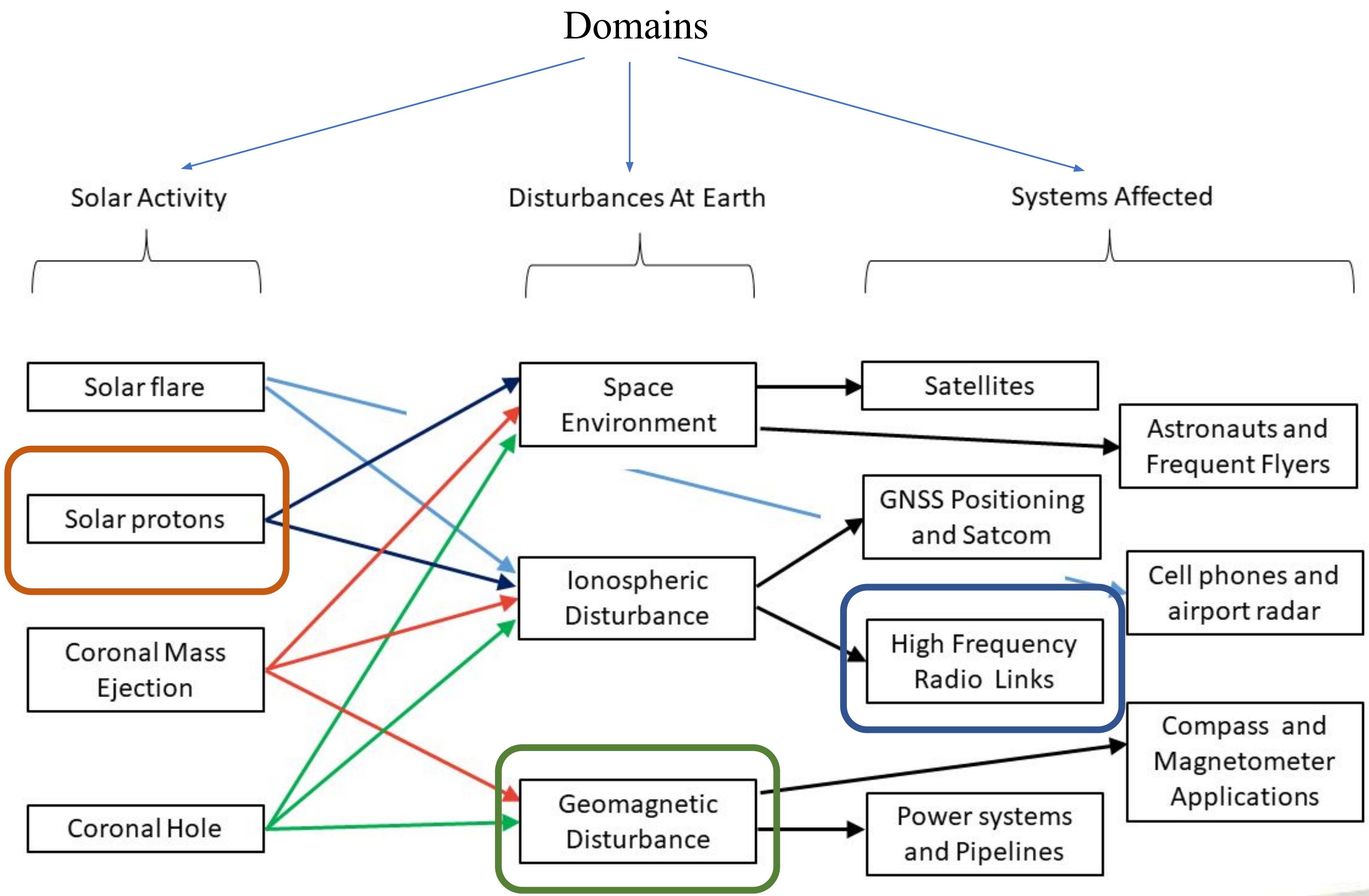
Be consistent

NOAA Scales

G Geomagnetic storms

S Solar Radiation storms

R Radio Blackouts



Session 2.2 Benchmarks, Metrics, and Scales

SWAG Co-Chairs: Kent Tobiska (SET), Craig Fugate (former FEMA), and Mike Stills (retired UA)

- Richard Horne (British Antarctic Survey)

Comments on Reasonable Worst Case Scenarios

Richard B. Horne FRS

British Antarctic Survey
Cambridge

SWAG, 19th January 2023

Reasonable Worst-Case Scenarios

- Developed in response to a Government request by the Space Environment Impacts Expert Group
- Set of scenarios – each aimed at a key area – not a uniform methodology – too complex
- Focus on a natural environment that could disrupt key infrastructure
- Officials could then discuss resilience with Government Depts., and operators of that infrastructure
- Results published in a peer reviewed paper – Hapgood et al., *Space Weather*, (2021)

- Used examples where we have experienced 1 in 100-year events – e.g., 1859,
- Also events such as 2003 which had a big impact. Result – identify new risks – e.g., multiple storms, fast solar wind
- Used analysis when available for a 1 in 100-year event – e.g., dB/dt, electron flux

- Work supported National Risk Register (2020), Nat. Space Strategy (2021), Severe SW Preparedness Strat. (2021)
- Close collaboration – Scientists, Agencies, Defense, Companies and Government – Policy, mitigation

- Session focus (Seth Jonas)
  - By Friday, what are the recommendations that should be made to SWORM?
  - Speakers and commenters should provide new, additive, and changed information
  - How best to coordinate US and international partner activities where there is mutual interest?
  - Are the best data currently being used to inform the discussions?
  - How can benchmarks, metrics and scales be made more useful?
  - Where are there gaps?
  - Look at maturity, complexity vs. opportunity to collaborate, what needs to be created or refined, what are the priorities?

- Aviation (Mike Stills)
  - NOAA space weather scales have strategic/tactical standard since 2000
  - Low latitude routes -HF communication impacted D-region absorption, SATCOM limits.
  - Hi latitude routes – HF communication impacted by polar absorption, Iridium not common.
  - Boteler will have insights into HF over Canada
  - FAA regulatory requirement – air carriers must be able to communicate with aircraft. Rapid and reliable communication within 4 minutes (CFR 121.99)
  - Outside of deviations due pandemic and geo-political sanctions baseline normalization.
  - Air Traffic-hi density environments (e.g. NAT Tracks) – likely require education to allow for standardization and coordination in the event of critical solar event (school of fish). Pilots want to know worst case radiation scenario, e.g., “what’s my risk?” Can agencies help with ALARA education and data validation?
  - International operators provide global commerce must consider fuel optimization for efficiency and impact to carbon environment – are there recommendations?

LUNCH
11:45 AM – 12:45 PM ET

2.3: Data Infrastructure and Methods

SWAG Co-Chairs: Jenn Gannon (CPI) and Tamas Gombosi (UMich)

- Sage Andorka (Space Force)
- Enrico Camporeale (University of Colorado)
- Rebecca Ringuette (NASA GSFC)
- Jacob Bortnik (UCLA)

2.3: Data Infrastructure and Methods

SWAG Co-Chairs: Jenn Gannon (CPI) and Tamas Gombosi (UMich)

- Sage Andorka (Space Force)

Space Force Data Architecture

19 January 2023

Sage Andorka
Deputy Chief and Chief Engineer
Cross Mission Data
Space Systems Command
(Also the Space Weather Engineer for Space Domain Awareness)

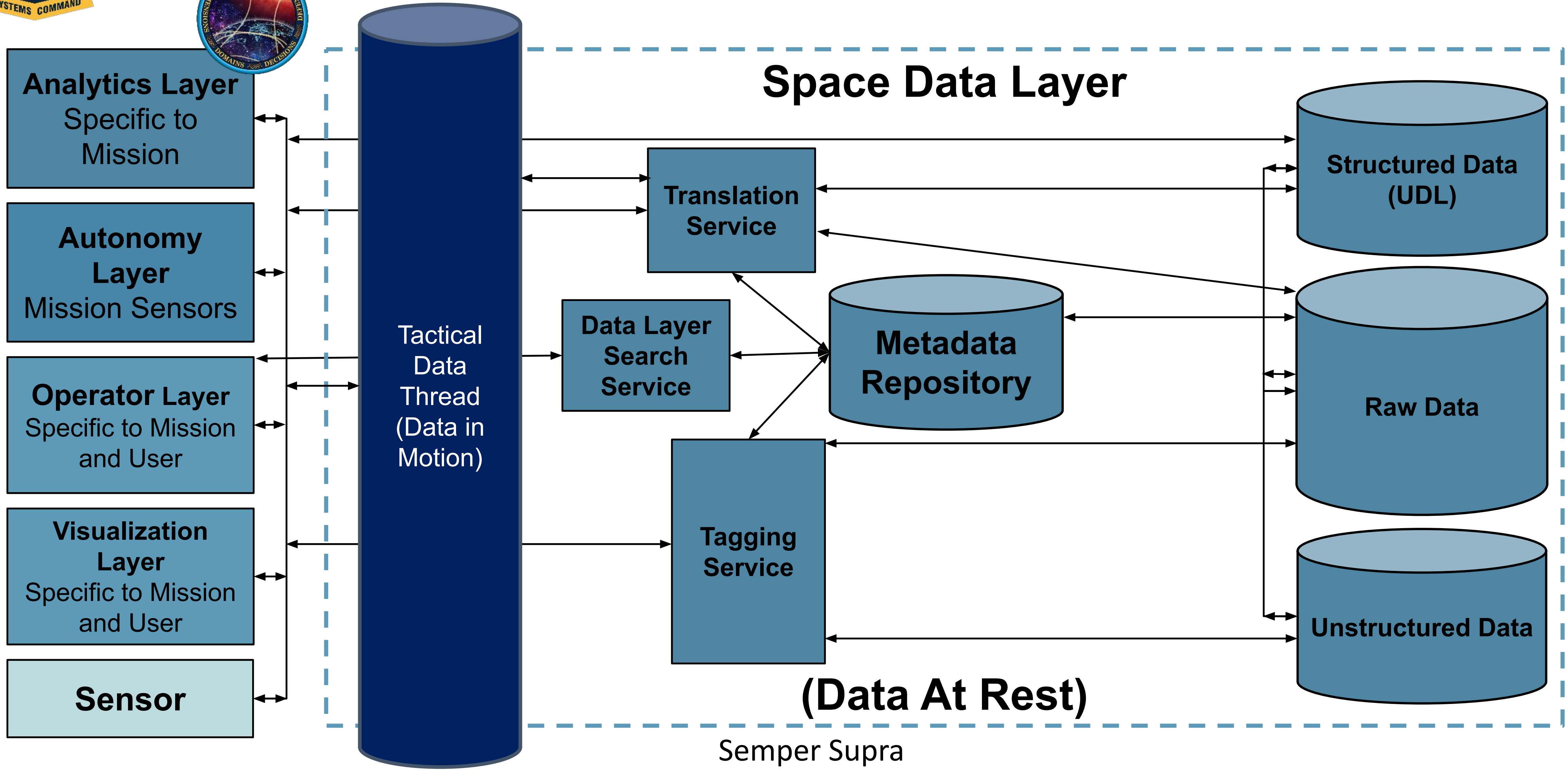
Semper Supra

Distributed Architecture OV-1

Data Library Tenets

1. The data must be adequately secured
2. The data owner must be able to control access to their data
3. Persist and expose data in a manner that allows for it to be optimally exploited
4. Must not limit the technology set of the end user
5. Users must be able to easily, intuitively and autonomously discover/ingest new data sources
6. Incentivize data owner participation
7. Guarantee an identical interface across all environments (U, S,TS, SAP)
8. Must be able to support the fundamental data distribution use cases (Req/Res, Pub/Sub, bulk delivery)

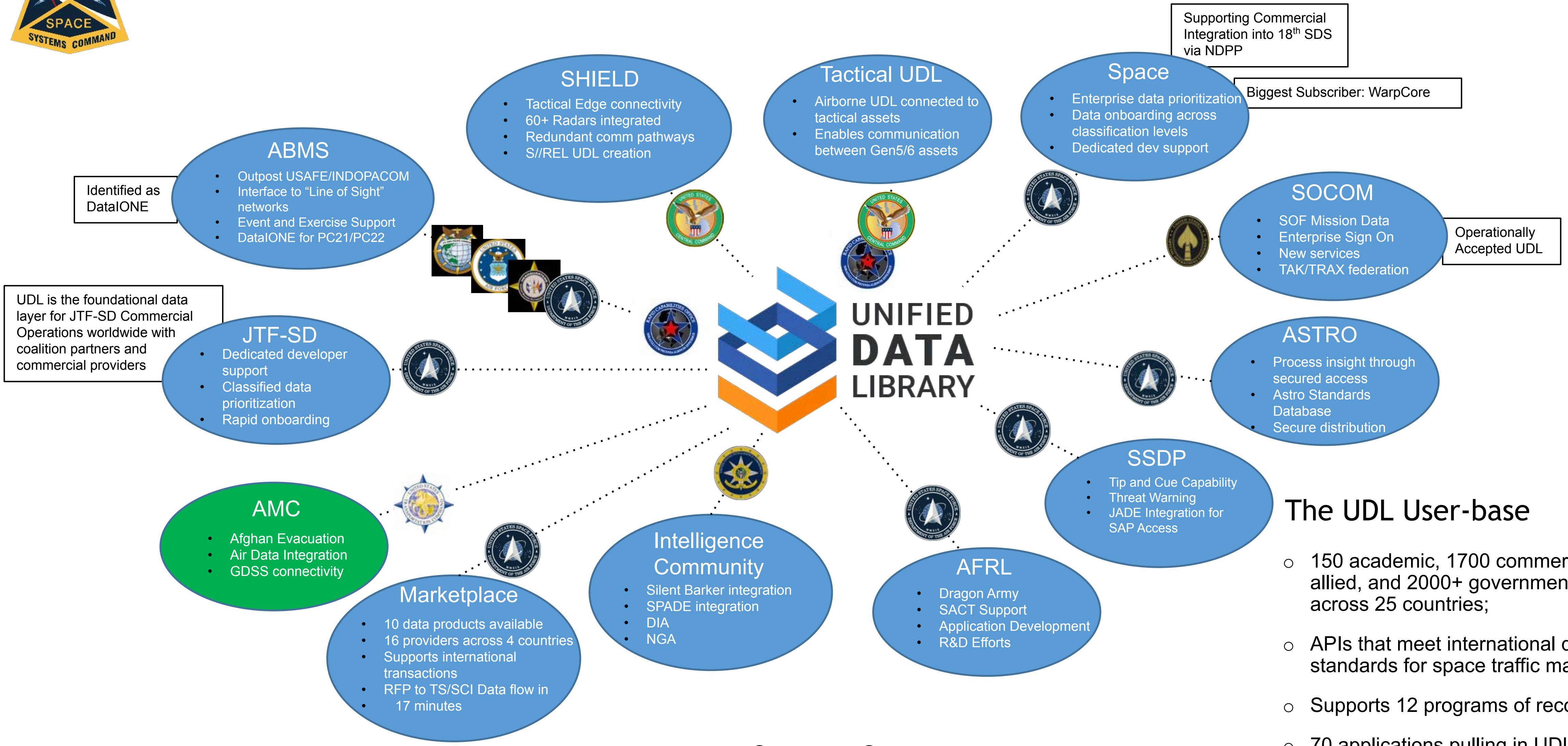
Space Data Layer Digital Twin



Semper Supra

Distribution A, approved for public release.

Who UDL Supports



The UDL User-base

- 150 academic, 1700 commercial, 125 allied, and 2000+ government accounts across 25 countries;
- APIs that meet international data standards for space traffic management
- Supports 12 programs of record
- 70 applications pulling in UDL data; 15 million observations pulled/day

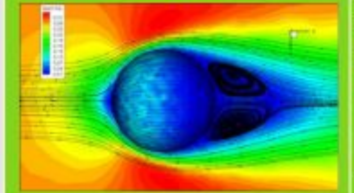
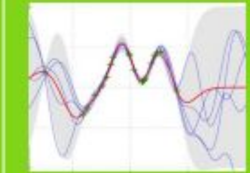
Semper Supra

2.3: Data Infrastructure and Methods

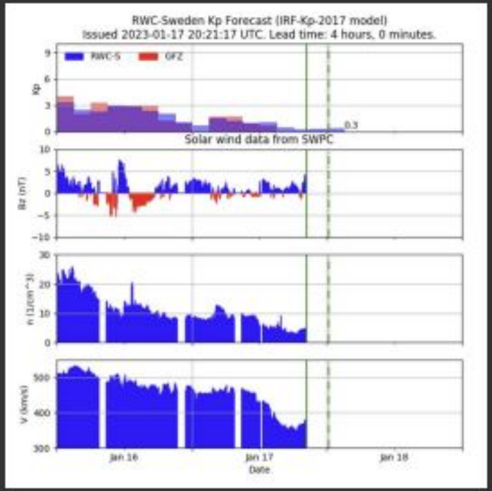
SWAG Co-Chairs: Jenn Gannon (CPI) and Tamas Gombosi (UMich)

- Enrico Camporeale (University of Colorado)

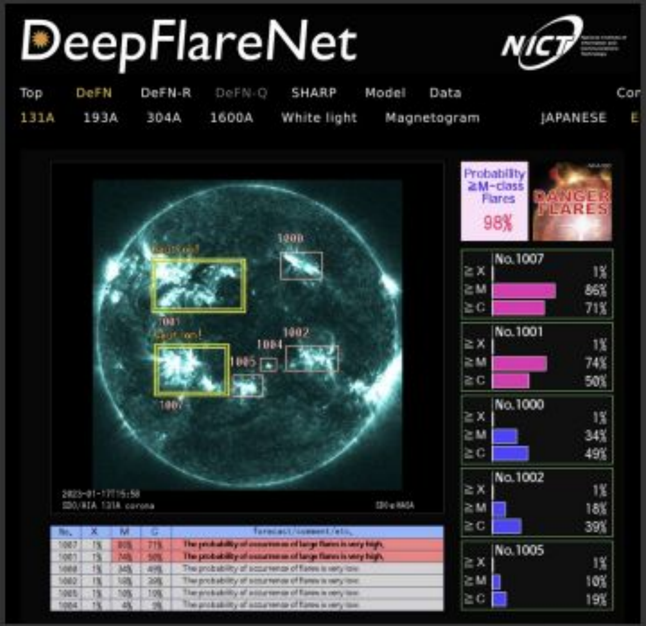
ML will become the standard way of SWx forecasting by the end of the decade

	Computationally affordable & faster than real-time	**Actionable** (lead-time & Uncertainty Quantification)	**Accurate**
WSA/ENLIL	1 – 3 days ahead prediction	No uncertainty	No better than persistence
SWMF (Geospace)	20 – 60 mins ahead	No uncertainty	No better than persistence
WAM/IPE	2 days ahead prediction	No uncertainty	Not sure about validation
Machine Learning	Run on a laptop (+100x speed-up)  Physics emulator	Ensemble or bulit-in UQ  	

https://swx-trec.com/dst/



https://swe.ssa.esa.int/irf-federated



https://defn.nict.go.jp/top_eng.html

See also:

https://spaceweather.gfz-potsdam.de/products-data/forecasts/

AI/ML will happen no matter what!

My very personal list of recommendations:

- Support ML competitions
  - Competitions are the quintessential citizen science projects
  - Change of mindsets: competitions are a “way of doing science”, and physicists should accept that an outsider community can crack a problem they have been working on for decades
- Support open data
  - For example, many SWPC output models are “public” but not really accessible
- Support ML-specific grants
  - For instance, a ML version of the NASA O2R2O grant would advance SWx enormously

Enrico.Camporeale@colorado.edu All views are mine. I do not represent NOAA, SWPC nor CU.

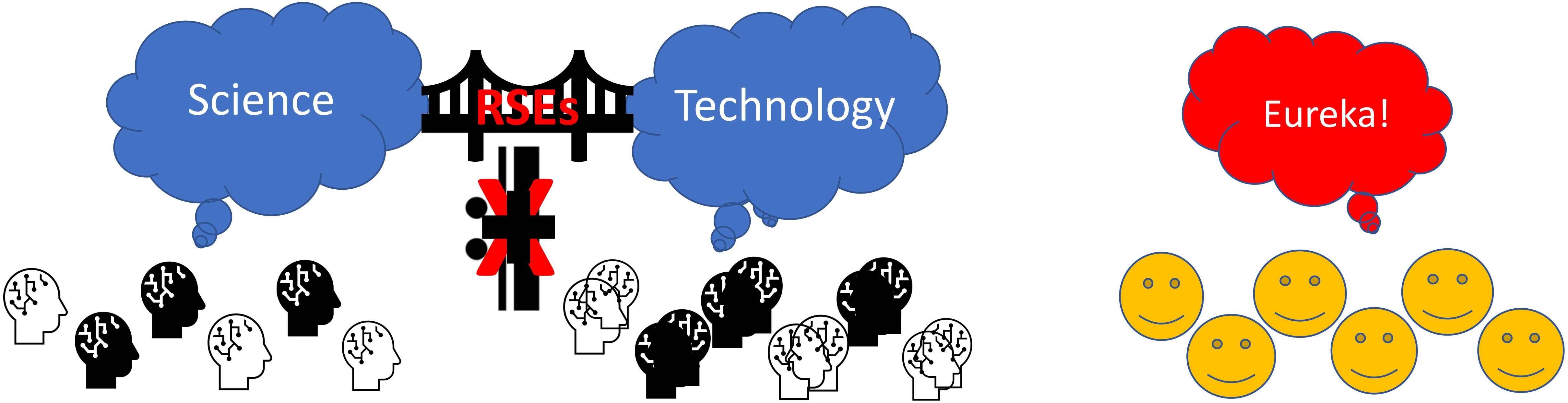
2.3: Data Infrastructure and Methods

SWAG Co-Chairs: Jenn Gannon (CPI) and Tamas Gombosi (UMich)

- Rebecca Ringuette (NASA GSFC)

Including Research Software Engineers on the Team: A recipe for success

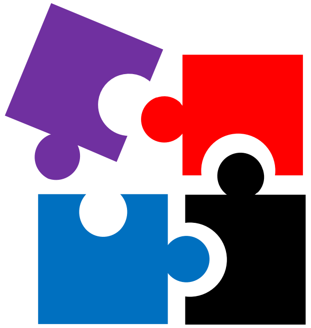
Dr. Rebecca Ringuette



Research software engineers are scientists that speak the language of software and software engineers that speak the language of science.

Why include Research Software Engineers?

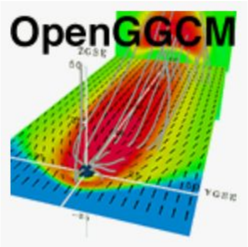
- **Accelerate research** to operations transition and the R2O2R feedback cycle.
- Apply universal design concepts to forecasting and validation tools to **increase accessibility** *(e.g. HelioViewer, CCMC/iSWA, CCMC/CAMEL).*
- Incorporate technology into science to enable **reusability**.
- Easily harness research advances to improve forecasting through **plug-and-play software design**.
- Apply modern computational methods to intelligently **accelerate calculations** *(e.g. GPU, AI/ML, data mining).*
- Create and maintain virtual environments to **simplify collaboration** *(e.g. CCMC-SWPC ACE, CCMC, HelioCloud).*
- Apply a new generation of **visualization technology** for research, operations and outreach *(e.g. AR/VR technology, NASA Scientific Visualization Studio, OpenSpace, CCMC/Kamodo).*
- Use software expertise to simplify **interoperability** *(e.g. CCMC/Kamodo, HAPI, CDAWeb).*



Related white paper
from the 2024 Heliophysics Decadal
10.22541/essoar.167397417.74606224/v1

AMGeO

GAMERA

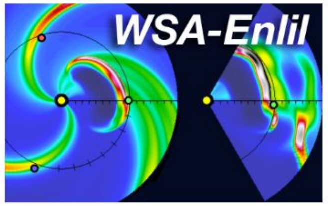


Center for Space Environment Modeling

SWMF

Space Weather Modeling Framework

Space@VT SuperDARN



+

Community Coordinated Modeling Center

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ensemble

dask

aws

docker

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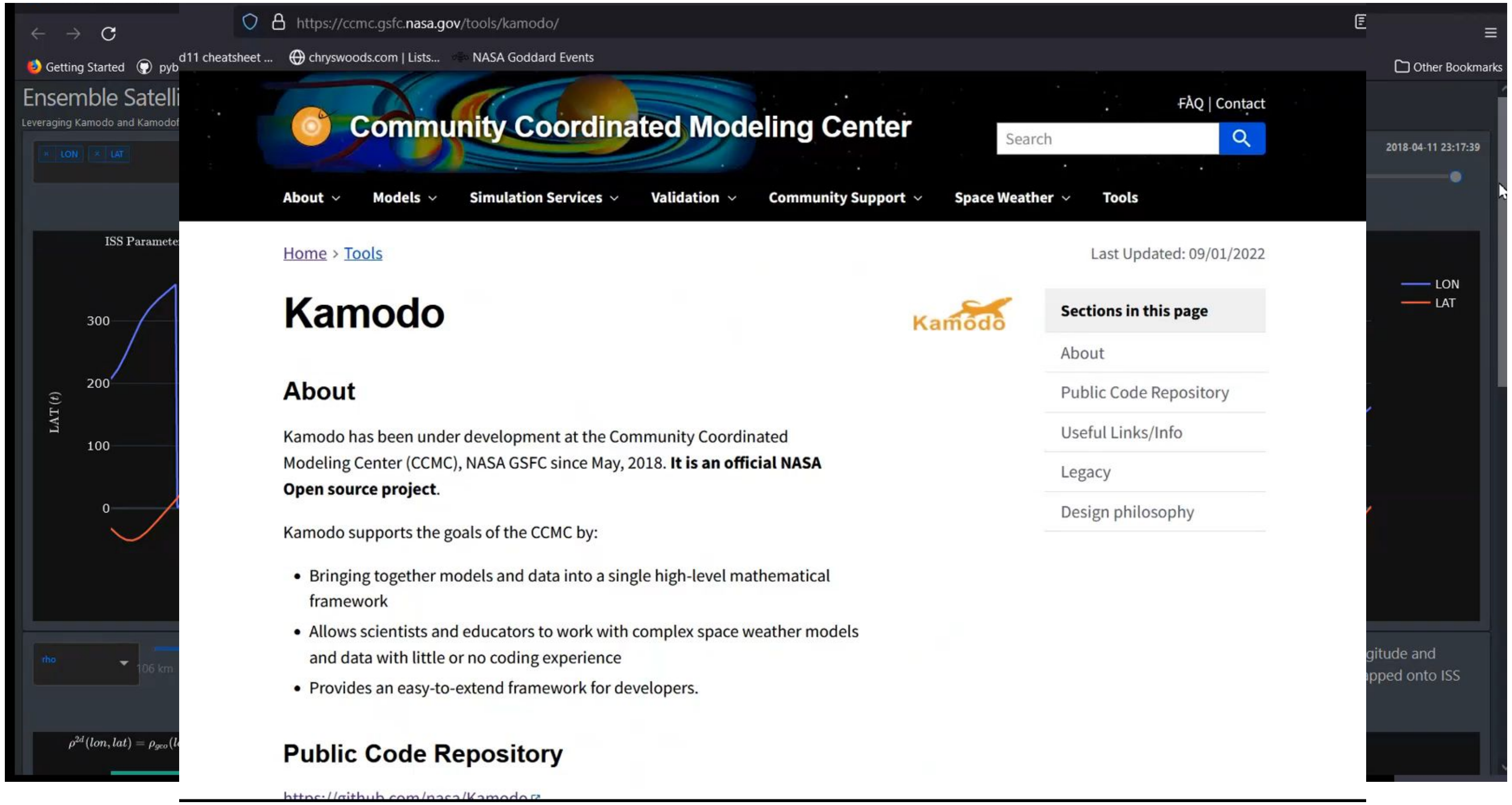
Kamodo-Core Github

Kamodo

CCMC-Kamodo Github



DOIs: 10.21105/joss.04053, 10.3389/fspas.2022.1005977, 10.22541/essoar.167214257.73153757/v1

2.3: Data Infrastructure and Methods

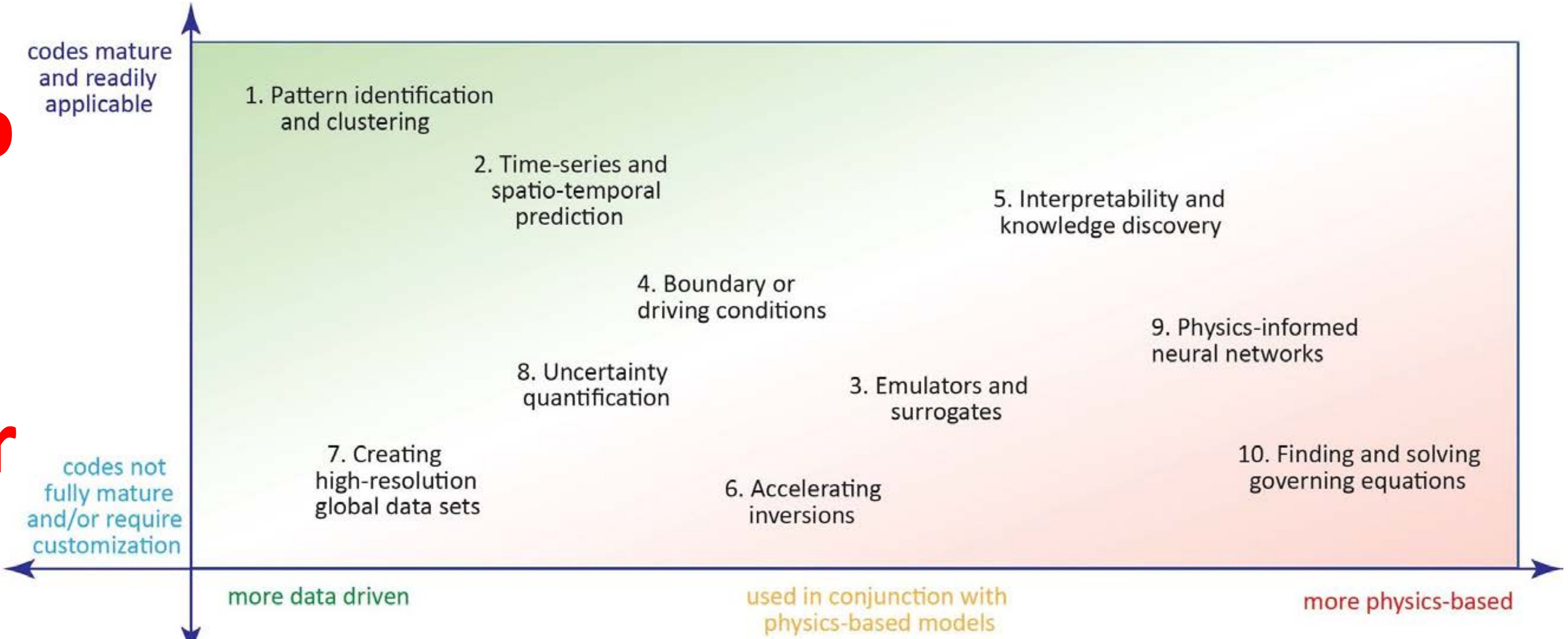
SWAG Co-Chairs: Jenn Gannon (CPI) and Tamas Gombosi (UMich)

- Jacob Bortnik (UCLA)

Potential of ML to support space weather op's

- Data volumes are growing, can't do science the "traditional" way; ML supersedes physics-based models in many cases ; students need to build ML models themselves
- Many space weather domains:
  - Solar flare/CME forecasts: hard; small scale and uncertain initiation process
  - GICs: hard: small spatial scales with intense events; not dense enough magnetometer coverage of US continent, utility transformer-level data very hard to obtain.
  - Solar wind: hard/medium: quiet solar wind is doable, CMEs are hard, stream-interaction-regions (CIRs) very hard; variable lag between solar disk features and L1 observations.
  - Space environment: medium: radiation belts (high energy trapped electrons and protons) retro- and now-cast models already achieved, gets harder with lower energies.
  - Geomagnetic indices: easy to hard: within ~1 day is doable now, ~2-7 is probably doable in next 5 years, >7 days (??)
- We can use mostly existing data for many applications
  - New observations needed for GICs

Potential of ML to support space weather op's: considerations for national strategy



Bortnik, J., and E. Camporeale (2021), Ten ways to apply machine learning in Earth and space sciences, *Eos, 102*, https://doi.org/10.1029/2021EO160257.

Suggested needs and opportunities

- Real-time data feeds: solar disk/solar wind/ geomagnetic index observations
- Funding to develop ML models: using existing tools and data
- Funding to develop relevant ML tools: some probs don't have canned soln's
- Expand observations in "key" regions (depends on space weather domain)
- Invest in education: train students/postdocs; workshops/meetings; materials

2.4: Evolving Infrastructure Systems and Services

SWAG Co-Chairs: Seth Jonas (Lockheed) and Mark Olson (NERC)

- Emanuel Bernabeu (PJM)
- Steve Stone (Lockheed Martin)
- Yari Collado-Vega (NASA GSFC)
- Rich DalBello (NOAA NESDIS, Office of Space Commerce)

2.4: Evolving Infrastructure Systems and Services

SWAG Co-Chairs: Seth Jonas (Lockheed) and Mark Olson (NERC)

- Emanuel Bernabeu (PJM)

Evolving Infrastructure Systems and Services

The Power Grid & Space Weather Strategy

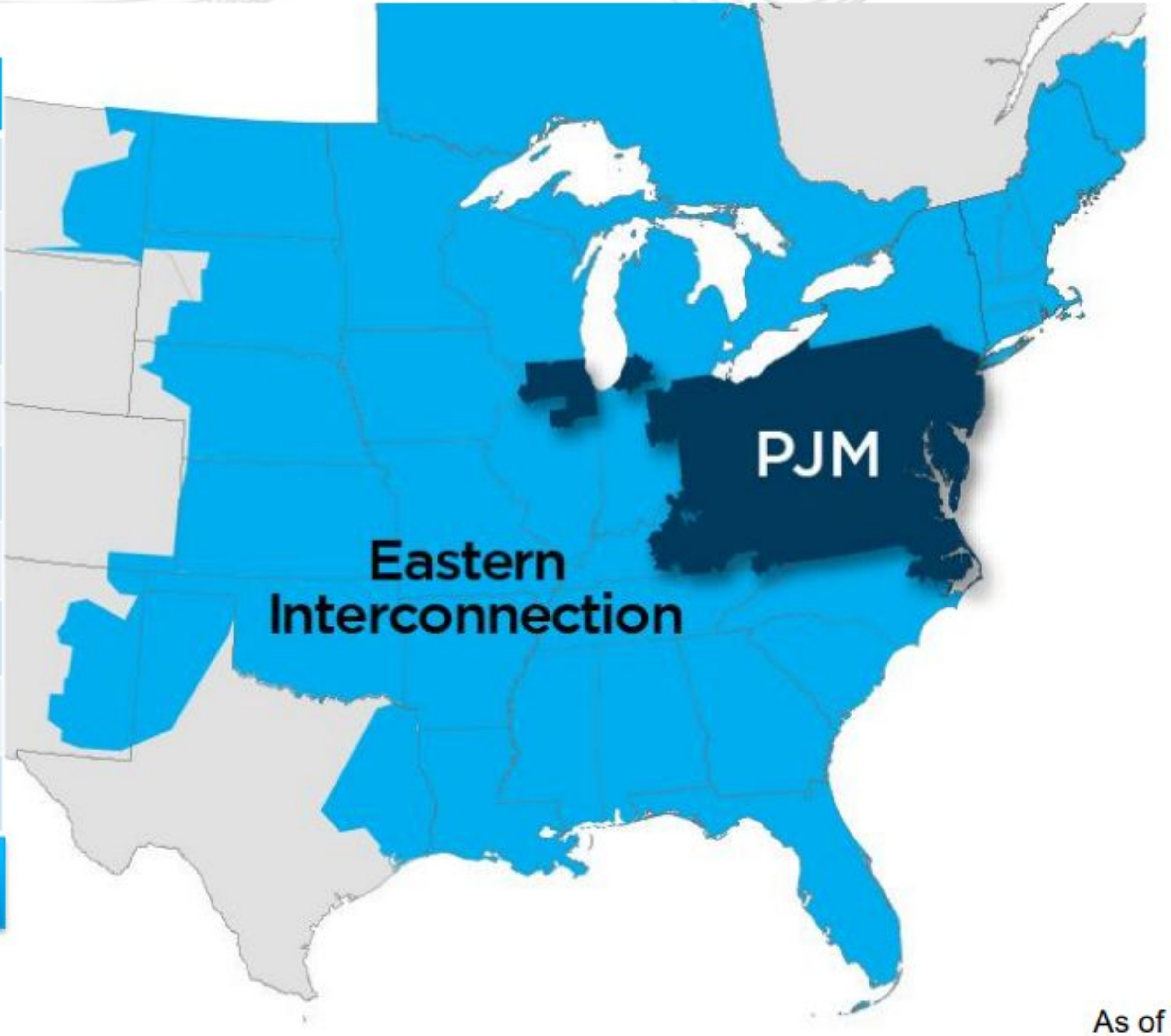
Emanuel Bernabeu, Ph.D.
Sr. Director, Applied Innovation & Analytics
PJM Interconnection

SWAG – National Space Weather Strategy and Action Plan
01/19/2023

PJM as Part of the Eastern Interconnection

Key Statistics	
Member companies	1,060+
Millions of people served	65
Peak load in megawatts	165,563
Megawatts of generating capacity	185,442
Miles of transmission lines	85,103
2020 gigawatt hours of annual energy	782,683
Generation sources	1,436
Square miles of territory	368,906
States served	13 + DC

21% of U.S. GDP produced in PJM



As of 2/2021

Operations, Transmission Planning, & Markets

Evolution of the Grid & Space Weather Strategy

Evolution of the Grid

- Renewable Resources (inverters)
- Electrification
- Distributed Energy Resources

Space Weather Strategy

- Magnetometers (Model Validation)
- Regional Forecast in V/km
- Continuously refine 1-100 year event

GMD Risk

1) Voltage Collapse – More likely in “weaker power grids”
2) Potential Equipment Damage (as the science evolved, this has become less concerning)

2.4: Evolving Infrastructure Systems and Services

SWAG Co-Chairs: Seth Jonas (Lockheed) and Mark Olson (NERC)

- Steve Stone (Lockheed Martin)

LOCKHEED MARTIN

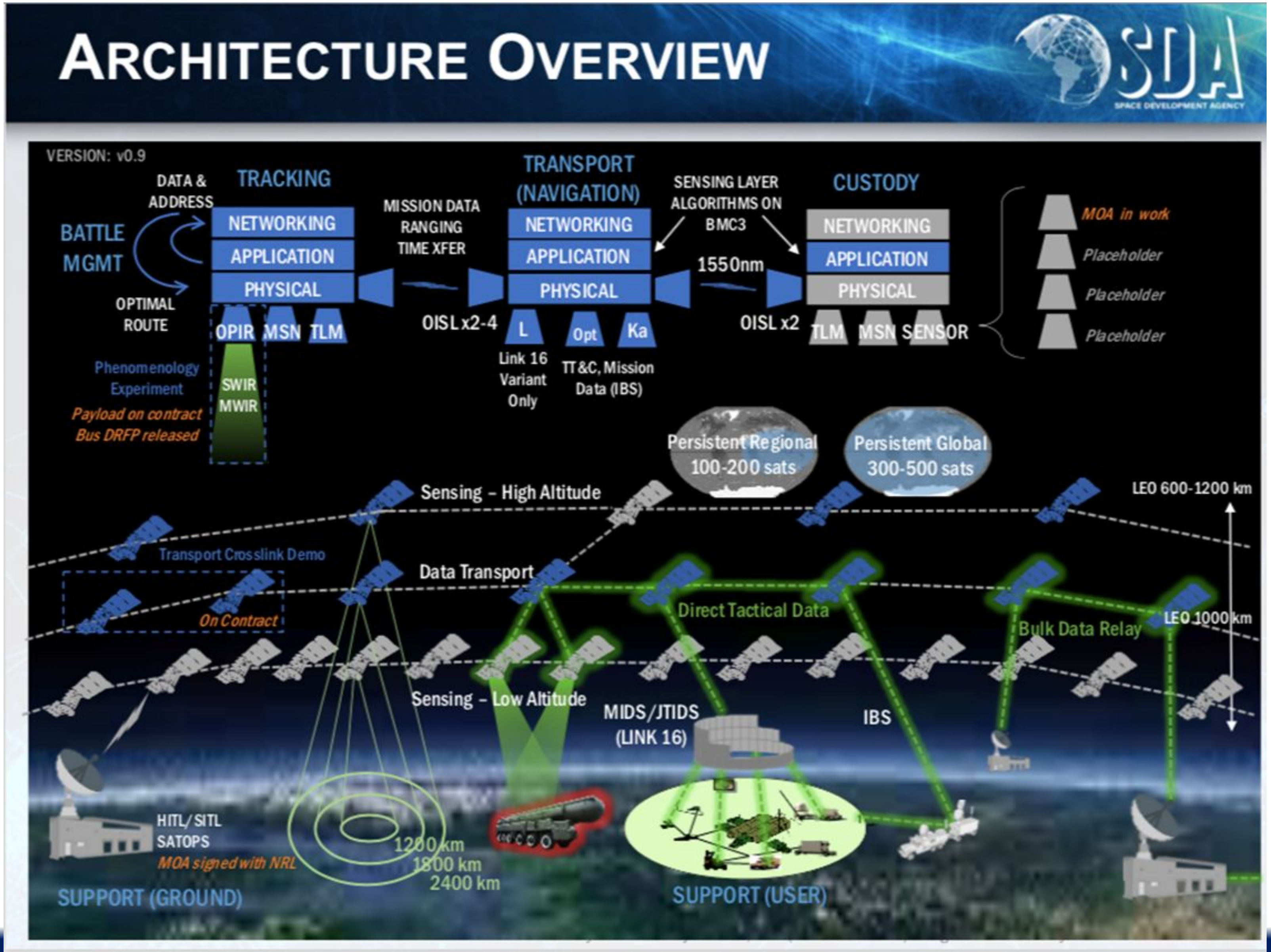
Industry Perspective of a Space Weather Data User: Space Development Agency - Transport Layer

Space Weather Advisory Group Meeting

Stephen Stone

Lockheed Martin Associate Fellow

SDA Architecture



2.4: Evolving Infrastructure Systems and Services

SWAG Co-Chairs: Seth Jonas (Lockheed) and Mark Olson (NERC)

- Yari Collado-Vega (NASA GSFC)

Capabilities Needed in Support of Human Space Exploration
SWAG Meeting: *Evolving Infrastructure Systems and Services.*
Dr. Yaireska (Yari) Collado-Vega, NASA GSFC

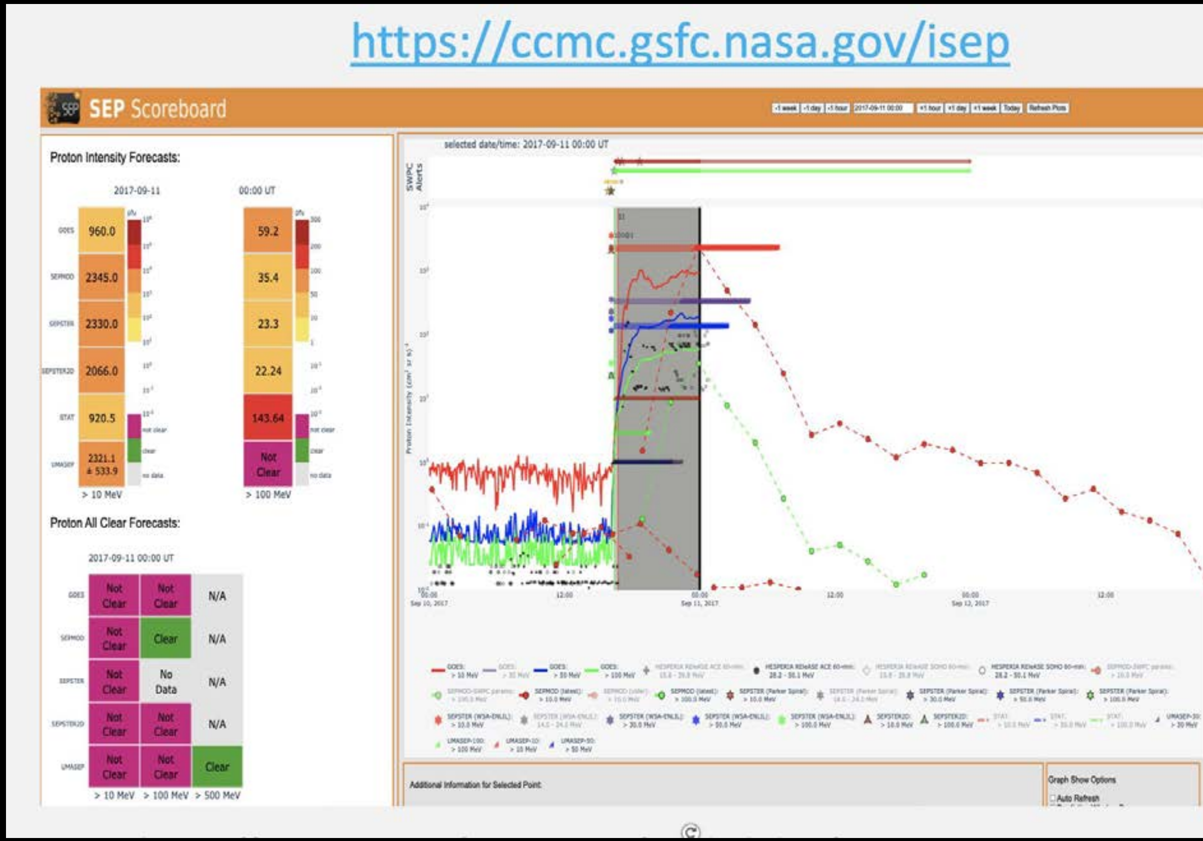
As NASA plans for missions beyond the Low Earth Orbit (LEO), new advancements in modeling, observations, and communications are needed to establish a suitable monitoring and protection environment for the missions and the crew. Efforts have been made to identify the gaps and to study the space weather architecture needed to support the new steps (NASA Gap Analysis Report, 2021; NESC Space Weather Architecture Report, 2020).

Needs:

- **Multipoint Solar Observations (L3-L4-L5 Missions)**
  - Coronagraphs/EUV/Magnetograms at L4 and L5 would provide improved capability to measure CMEs, to observe flare locations, and understand active region evolution. However, even having spacecraft at both L4 and L5 leaves the far side 60 degrees unobserved. A Sun-Earth L3 might close the gap, at least along the ecliptic, but would require communications relays. This will improve the modeling capabilities immensely.

- **Solar Polar Missions**
  - Polar views of the Sun are also essential for the understanding of the magnetic boundary on the Heliosphere. The background solar wind affects the propagation of the CMEs shocks associated SEPs. Polar observations are definitely needed to improve the understanding the solar magnetic dynamo used by the global models.

- **Data Availability and Acquisition**
  - The current DSN downlink schedule and capabilities already limit real-time data availability from SOHO and STEREO A coronagraphs. Those gaps, in turn, limit real-time space weather analysis capability and can affect predictions. Ground station redundancy is crucial for any data source that has operational needs.



- **International Collaboration**
  - **Model/Tool Development**

  NASA is incorporating the use of models such as REleASE (Posner 2007, currently updated through the EU HESPERIA collaboration) and UMASEP (University of Malaga) in their support for ISS and Artemis missions.
  - ISEP Project (NASA SRAG-CCMC-M2M)
    - Scoreboard developments to help the console operator on the decision making the the Flight Control Team.
    - Some models are dependent on CME measurements and CME simulations to produce a forecast.

- **Space Weather on Mars**
  - As we consider human exploration of Mars, the idea of an asset at the Sun-Mars L1 location should be considered to provide parallel observations with Mars to those near Earth. The Sun-Mars L4 and L5 locations are desirable for many of the same reasons as Sun-Earth L4 and L5, but Sun-Mars L4 and L5 observations would provide the added benefit of potentially closing the Sun-Earth farside problem. There is also a need for Earth-independent space weather/radiation assessment for crewed missions to Mars.

Currently, we rely on research missions to analyze the real time environment. As missions transition beyond LEO (into free space), many forecast and nowcast capabilities will become limited during both transit and on the lunar/planetary surface. As NASA looks to these future missions, measurements at varied locations, better data cadence and latency, and measurements away from the Sun-Earth line, are necessary to provide earlier assessments and therefore have more time to respond to an enhancement in the space environment. We are looking forward to the upcoming NOAA missions (GOES-U and SWFO) and the ESA Vigil mission, but a lot more is needed for Mars exploration.

*Collado-Vega et al., (2022), *Space Weather Operations and the need for Multiple Solar Observational Vantage Points*, White Paper Submitted to the Decadal Survey for Solar and Space Physics (Heliophysics).

2.4: Evolving Infrastructure Systems and Services

SWAG Co-Chairs: Seth Jonas (Lockheed) and Mark Olson (NERC)

- Rich DalBello (NOAA, Office of Space Commerce)

BREAK
3:00 – 3:30 PM ET

2.5: Industry and Government Collaborations, Coordination, Outreach, and Communications

SWAG Co-Chairs: Rebecca Bishop (Aerospace Corp) and Scott McIntosh (UCAR)

- Dipak Srinivasan (APL)
- Yuri Shprits (UCLA)
- Bob Arritt (EPRI)
- Erin Miller (Information Sharing and Analysis Center)

2.5: Industry and Government Collaborations, Coordination, Outreach, and Communications

SWAG Co-Chairs: Rebecca Bishop (Aerospace Corp) and Scott McIntosh (UCAR)

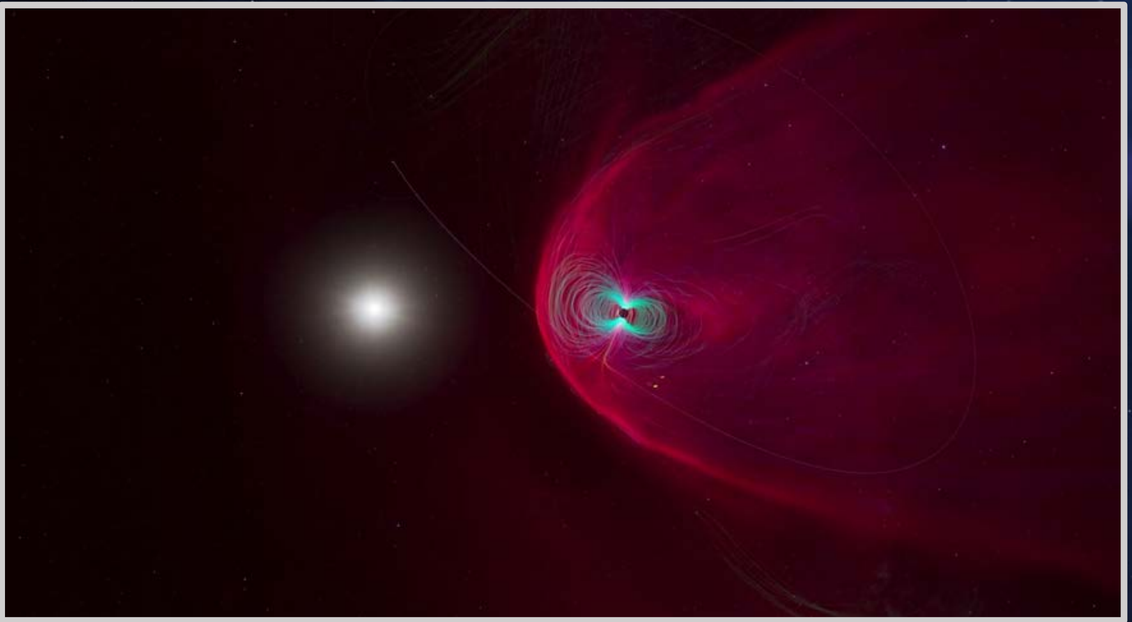
- Dipak Srinivasan (APL)

Space Weather Tabletop Exercise

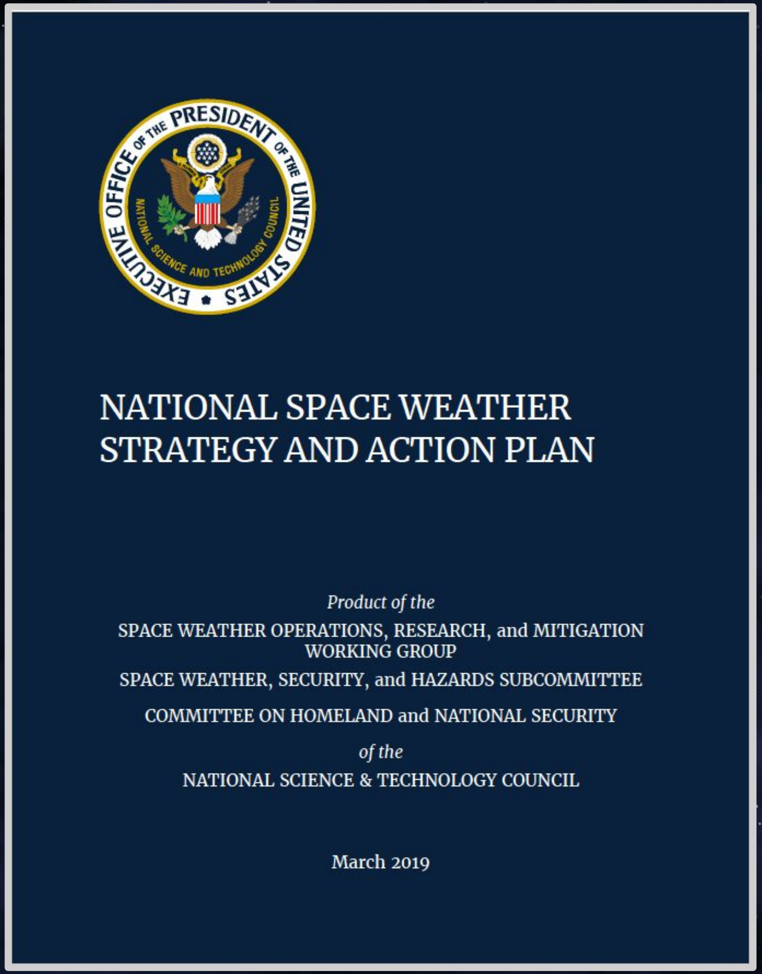
Briefing to joint Space Weather Advisory Group
January 19, 2023

Dipak Srinivasan
Manager, Civil Space Strategic Initiatives
Johns Hopkins Applied Physics Laboratory

Two Space Hazards



Two Space Hazards; Two National Strategy & Action Plans


NATIONAL SPACE WEATHER STRATEGY AND ACTION PLAN

Product of the

SPACE WEATHER OPERATIONS, RESEARCH, and MITIGATION WORKING GROUP

SPACE WEATHER, SECURITY, and HAZARDS SUBCOMMITTEE

COMMITTEE ON HOMELAND and NATIONAL SECURITY

of the

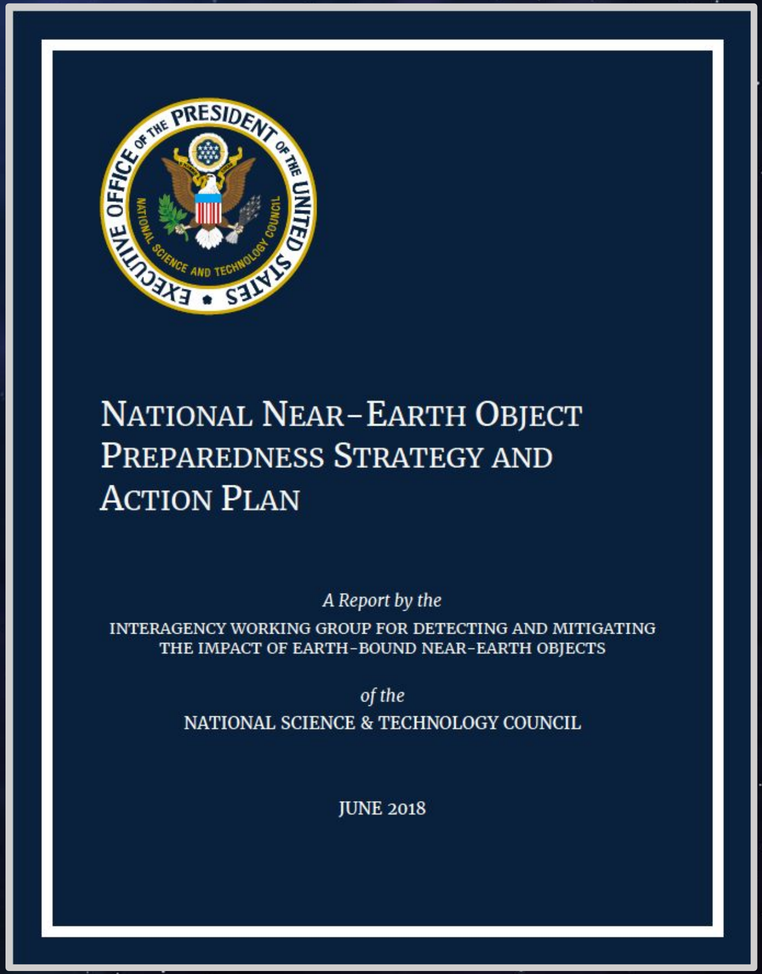
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

March 2019

§3.5 ***Exercise Federal response, recovery, and operations plans and procedures for space weather events.*** [Ongoing; DHS, DOC, DOD, DOE, DOS, DOT, and NRC]

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

§5.1 ***Develop a set of real-world scenarios based on credible impact threats with observable parameters to inform planning and procedure development.*** [Short term; FEMA, DHS, NASA]


NATIONAL NEAR-EARTH OBJECT PREPAREDNESS STRATEGY AND ACTION PLAN

A Report by the

INTERAGENCY WORKING GROUP FOR DETECTING AND MITIGATING THE IMPACT OF EARTH-BOUND NEAR-EARTH OBJECTS

of the

NATIONAL SCIENCE & TECHNOLOGY COUNCIL

JUNE 2018

Space Weather TTX

- Approaching Solar Max
- Unprecedented level of susceptibility
- Need for speed – get the word out fast

- Time
- Right people & organizations
- Right discussions

- Policy gaps
- Technology gaps
- Communications gaps

PDTTX4 included senior participants from OSTP • NSC • NSpC • NASA • FEMA • USSPACECOM • US Northern Command • NSF, Dept. of State • North Carolina and Winston-Salem Emergency Response

PDTTX4 After Action Report has helped define future investments

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

SWx TTX Potential Participants: Government Agencies

NSF

NASA

NOAA

Executive Office of the President – Office of Science and Technology Policy

Department of Energy

United States Space Force

National Security Council

National Space Council

U.S. AIR FORCE
557th WEATHER WING

USGS
science for a changing world

Department of Homeland Security
FEMA

State & Local Emergency Response

SWx TTX: Candidate scenario

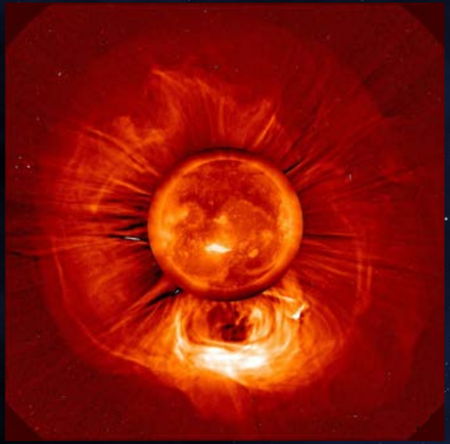
SWx Vulnerability	SWx Driver:			
	CME-triggered Geomag. Storm	*Fast-stream-triggered Geomag. Storm*	*Solar Energetic Particle Event*	*Solar Flare Event (incl. Solar Radio Bursts)*
Power Grid Damage	Possible	Unlikely	N/A	N/A
Satellite Comm/Nav Degradation or Outage	Likely	Likely	Possible	Likely
Satellite Drag and Collision Avoidance/Debris	Likely	Possible	Unlikely	Possible
Radiation Effects on Spacecraft and Aviation	Possible	Likely	Likely	Possible
Astronaut Health and Safety	Possible	Unlikely	Likely	Possible

- Goal would be to design a realistic scenario that touches on a large, but manageable, number of stakeholders
- Once we have all the interested stakeholders identified and on-board, we'll work to define objectives, and then design the scenario accordingly

"Perfect (geomagnetic) storm" scenario sketched out on next slide

SWx TTX: A Perfect (Geomagnetic) Storm

t_0: Solar Drivers



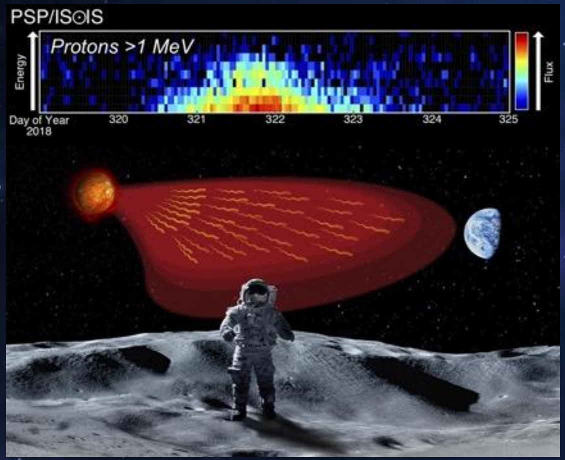
Intense solar flare, SRB, and CME erupt from solar active region

Worst-case effects:

Polar flights grounded

Sat-Com/Nav disruptions

t_0 + ~minutes: SEP



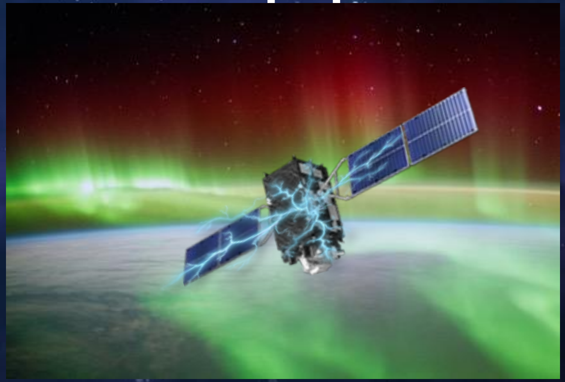
Solar energetic particle radiation arrives in geospace

Worst-case effects:

Astronaut health and safety threatened

Single event effects on spacecraft

t_0 + 15 hours: High-speed solar



Unpredicted high speed stream triggers storm

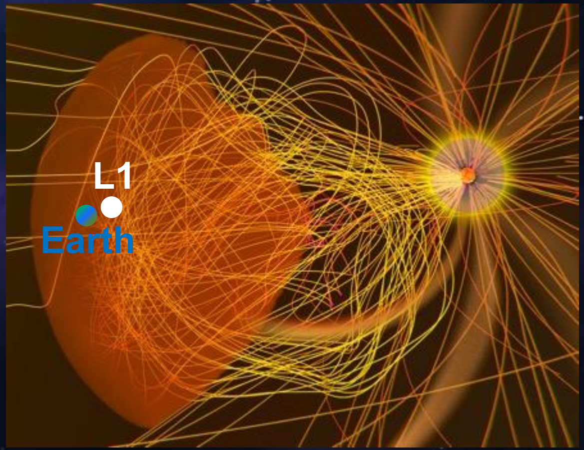
Worst-case effects:

Spacecraft charging & radiation damage

Increased satellite drag

Sat-Com/Nav disruptions

t_0 + 36-hours: CME impact and storm



CME impact triggers major geomagnetic storm

Worst-case effects:

Power outages/disruptions

Satellite losses to radiation & drag

Sat-Com/Nav disruptions

2.5: Industry and Government Collaborations, Coordination, Outreach, and Communications

SWAG Co-Chairs: Rebecca Bishop (Aerospace Corp) and Scott McIntosh (UCAR)

- Yuri Shprits (UCLA)

Combining Models and Observations by Means of Data Assimialtion

Yuri Shprits

Space Science Innovations, Inc.

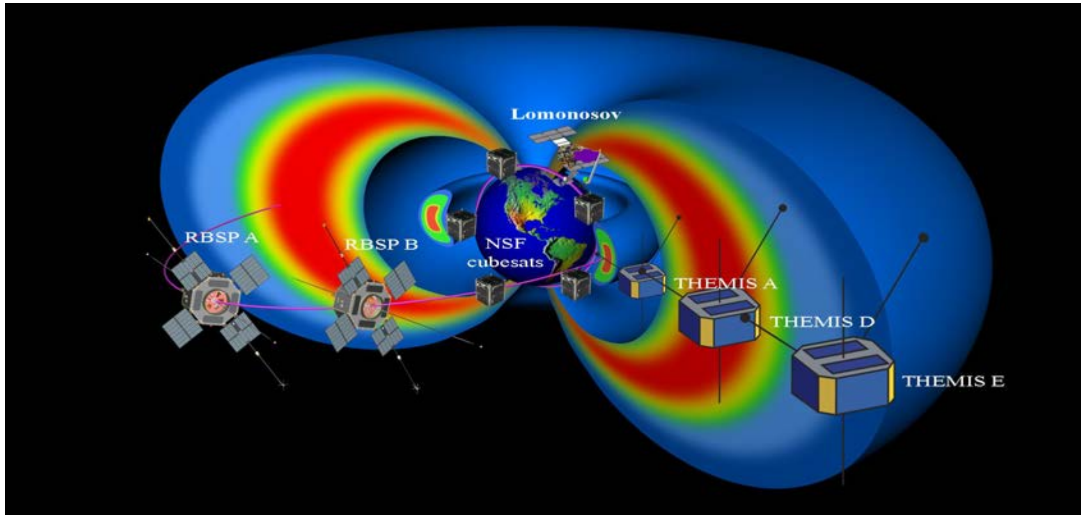
University of Potsdam/ GFZ Potsdam

EPSS UCLA

Data Assimilation: Combining Data With Observations

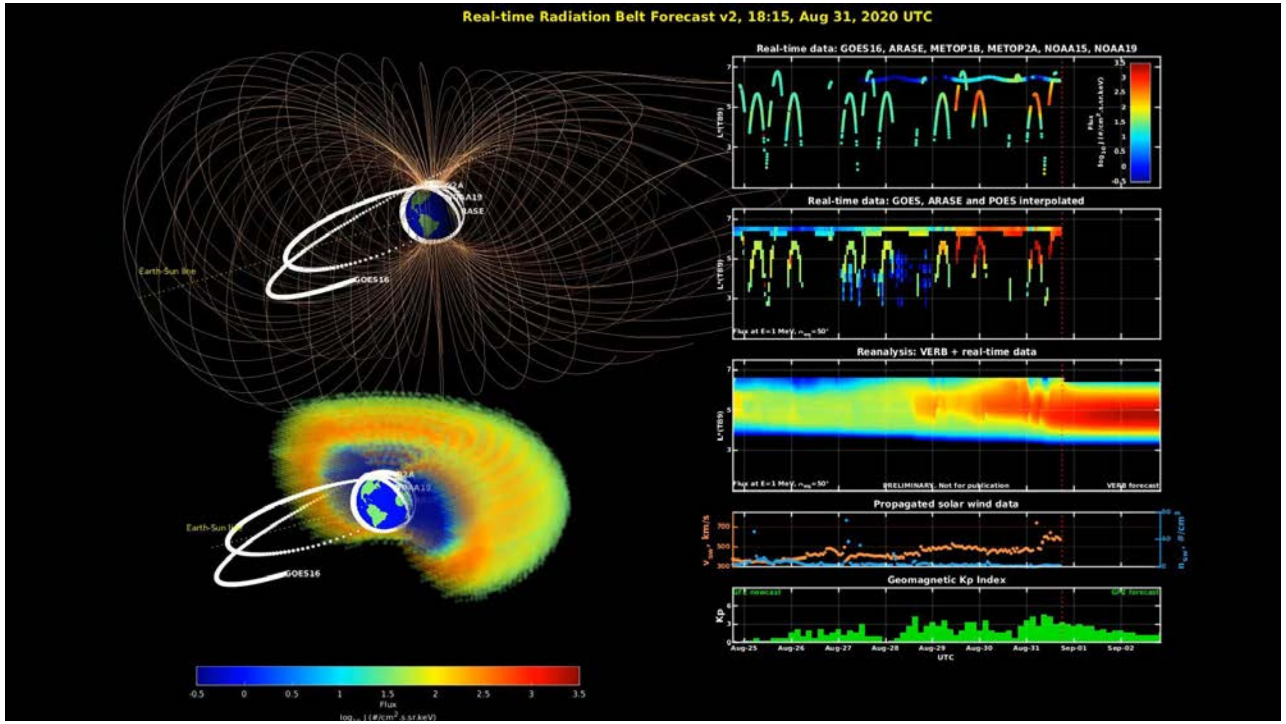
Data Assimilation allows to blend observations from various satellites with physics-based models

Vast amount of data from ongoing mission requires new methods to combine data ARASE, POES, THEMIS, MMS, CubeSats, GOES, GPS, etc.



Unlike ML models DA can give accurate predictions during extrema events.

Data assimilation combines data from different sources
This example: From GFZ, GOES, ARASE,METOPx2, NOAA/POESx2

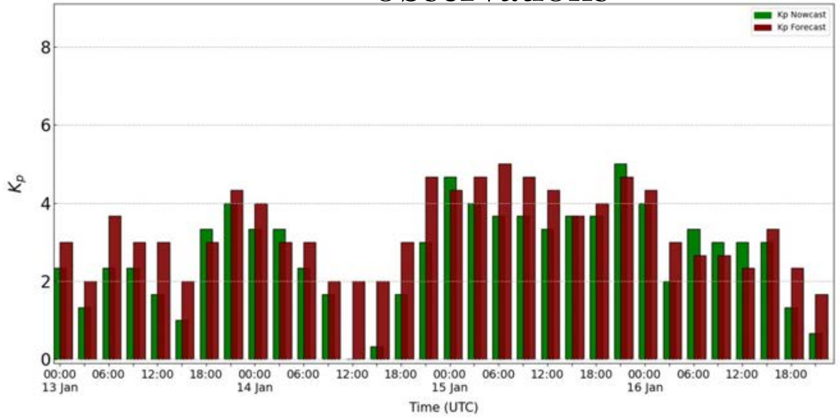


Operational at https://www.space-sci.com/real-time-forecast/
https://www.spacepager.eu/

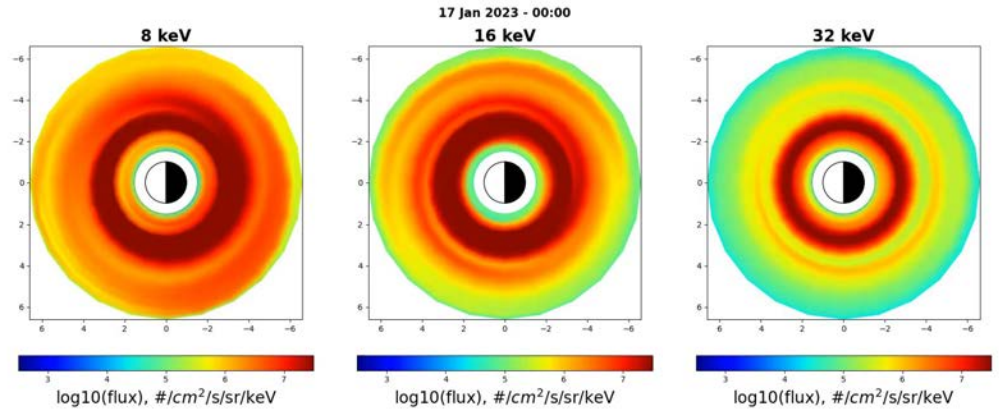
Real-time Space Weather Products

A number of space weather products have been already developed and operate in real time.

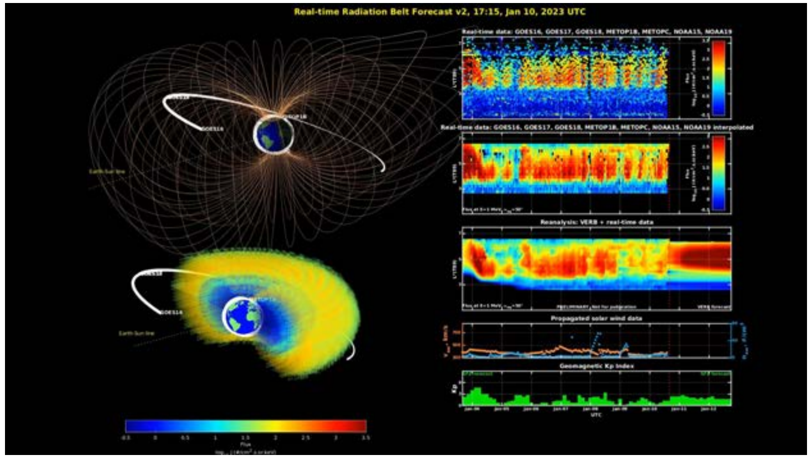
ML predictions of Kp and comparison with observations



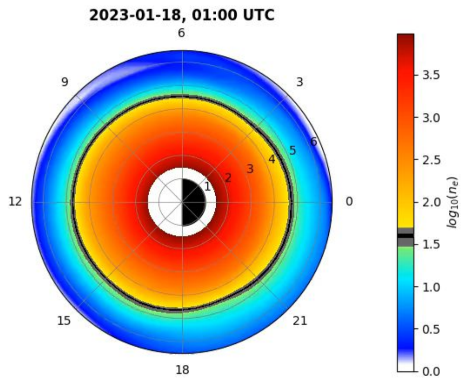
Data-assimilative ring current forecast



Data-assimilative radiation belt forecast



ML-based plasma density predictions



2.5: Industry and Government Collaborations, Coordination, Outreach, and Communications

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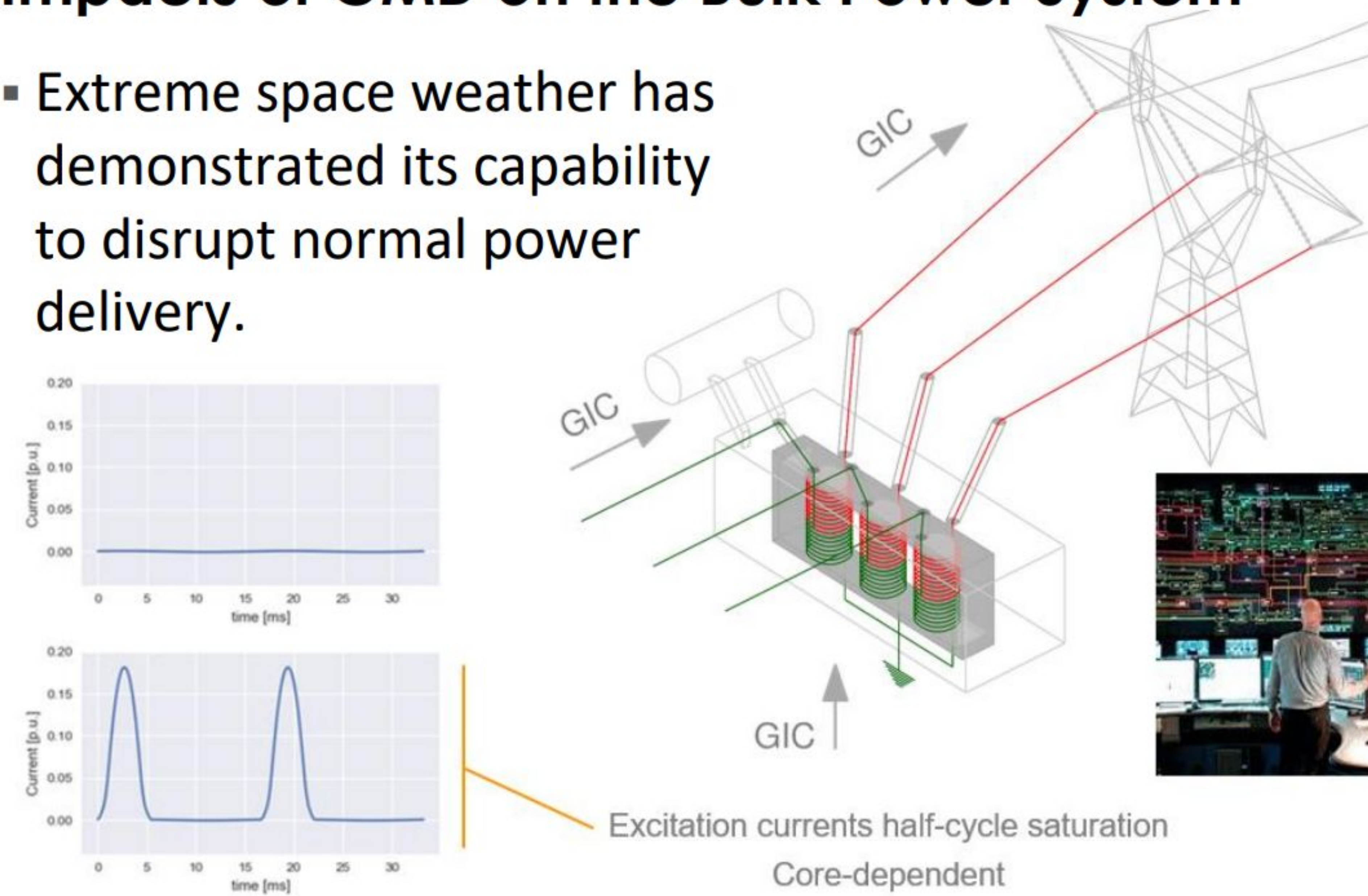
- Bob Arritt (EPRI)

Impacts of GMD on the Bulk Power System

- Extreme space weather has demonstrated its capability to disrupt normal power delivery.



EPRI

Cross-Sector Engagement

- NERC's GMD Meetings
- Collaborative Research
- Industry meetings
- NASA Engagement
- DOE Engagement
- NSF Workshops

Continued Engagement is Critical in GMD Preparedness

2.5: Industry and Government Collaborations, Coordination, Outreach, and Communications

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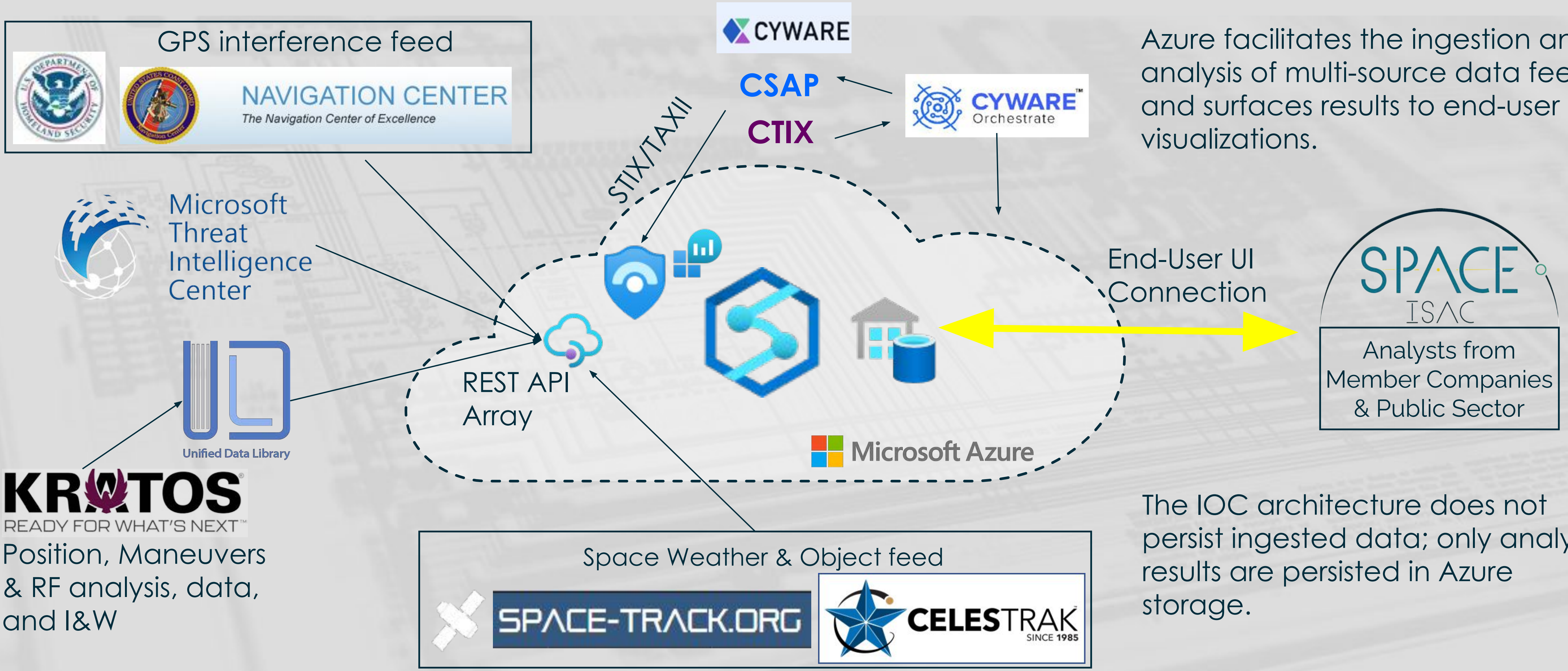
- Erin Miller (Information Sharing and Analysis Center)

IOC Data Architecture Concept

www.s-isac.org / erin@s-isac.org /Ph. 303-596-4370

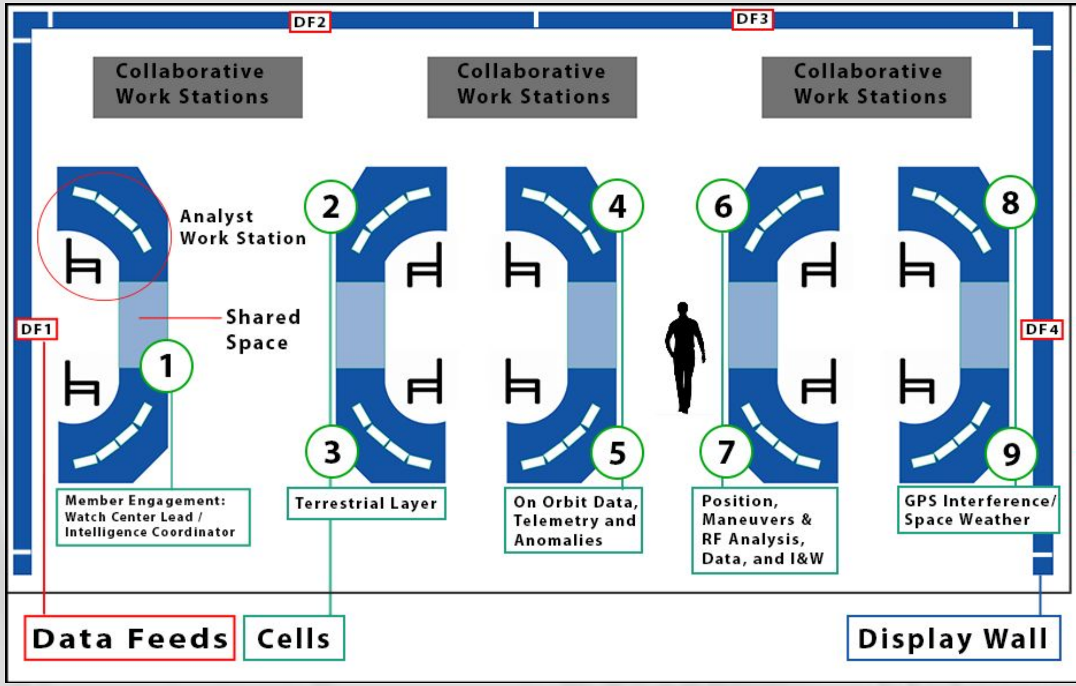


Azure facilitates the ingestion and analysis of multi-source data feeds, and surfaces results to end-user visualizations.

The IOC architecture does not persist ingested data; only analytic results are persisted in Azure storage.

Space ISAC Watch Center

Initial Operating Capability



Display Examples

The Watch Center's **data wall** will display visualizations and real time data feeds for Space ISAC Analysts.

The Watch Center floor will be organized by "cells" that correspond to **functional areas** related to use cases.

The **Member Engagement Cell** will be focused on facilitating communication between analysts and Space ISAC Members.

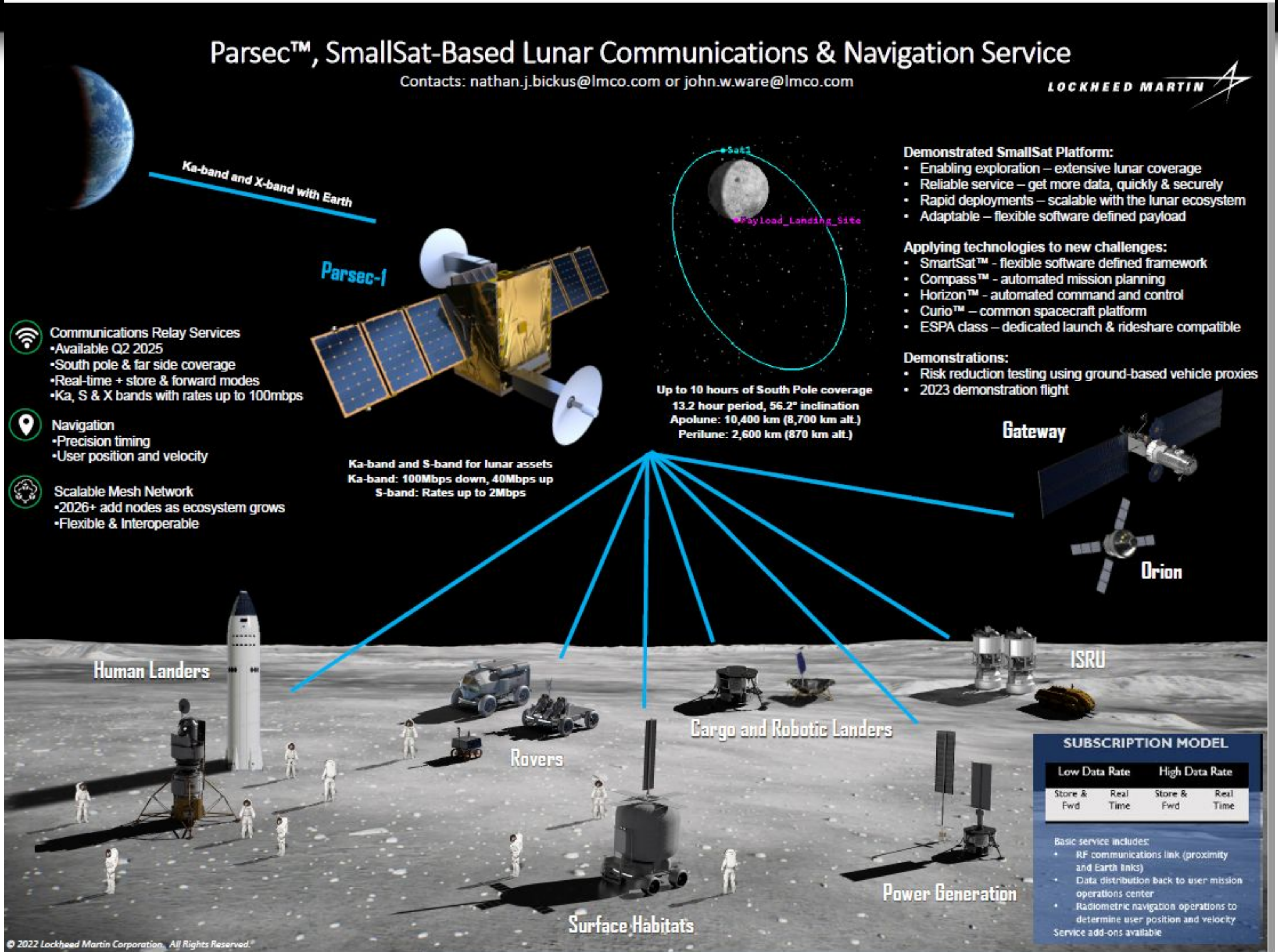
2.5: Industry and Government Collaborations, Coordination, Outreach, and Communications

Purpose: To determine the best strategy for engaging and maintaining connection between Industry and Government to improve utilization of Space Weather information and mitigate its impact.

1. What has been the key to past and continuing successful collaborations?
2. What are the most significant challenges associated with initializing collaborations and maintaining on-going coordination?
3. What is the most effective and preferred communication method for the private sector?

Public Comments
4:30 – 5:00 PM ET

Chris Leeds



Parsec™, SmallSat-Based Lunar Communications & Navigation Service
Contacts: nathan.j.bickus@lmco.com or john.w.ware@lmco.com
LOCKHEED MARTIN
Ka-band and X-band with Earth
Parsec-1
Communications Relay Services
•Available Q2 2025
•South pole & far side coverage
•Real-time + store & forward modes
•Ka, S & X bands with rates up to 100mbps
Navigation
•Precision timing
•User position and velocity
Scalable Mesh Network
•2026+ add nodes as ecosystem grows
•Flexible & Interoperable
Ka-band and S-band for lunar assets
Ka-band: 100Mbps down, 40Mbps up
S-band: Rates up to 2Mbps
Sat1
Payload_Landing_Site
Up to 10 hours of South Pole coverage
13.2 hour period, 56.2° inclination
Apolune: 10,400 km (8,700 km alt.)
Perilune: 2,600 km (870 km alt.)
Demonstrated SmallSat Platform:
• Enabling exploration – extensive lunar coverage
• Reliable service – get more data, quickly & securely
• Rapid deployments – scalable with the lunar ecosystem
• Adaptable – flexible software defined payload
Applying technologies to new challenges:
• SmartSat™ - flexible software defined framework
• Compass™ - automated mission planning
• Horizon™ - automated command and control
• Curio™ – common spacecraft platform
• ESPA class – dedicated launch & rideshare compatible
Demonstrations:
• Risk reduction testing using ground-based vehicle proxies
• 2023 demonstration flight
Gateway
Orion
Human Landers
Rovers
Cargo and Robotic Landers
ISRU
Surface Habitats
Power Generation
SUBSCRIPTION MODEL
Low Data Rate
High Data Rate
Store & Fwd
Real Time
Store & Fwd
Real Time
Basic service includes:
• RF communications link (proximity and Earth links)
• Data distribution back to user mission operations center
• Radiometric navigation operations to determine user position and velocity
Service add-ons available
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It’s Time for a Space Weather Constellation

Paul Boerner

Terrestrial weather forecasting is impossible without measurements of the whole Earth. Similarly, improving our ability to understand and predict space weather demands new observations:

- **Global** measurements of the solar magnetic field and the configuration of the lower corona **at all solar longitudes** to predict solar eruptions, including those triggered by events on the far side of the sun;
- **Widely distributed** measurements of the heliospheric field and solar wind configuration to predict the effects of solar activity on Earth;
- Space weather **throughout the solar system**, not just at Earth, can affect human activity, including crewed and robotic space exploration. Global observations of the solar drivers and the environment through which events propagate are essential.

Simultaneously, technology and the accelerating commercialization of space have enabled lower launch costs, more capable instruments, and on-board intelligence. To take advantage of the convergence of these trends and fill the gap in space weather observations, it is time for the United States to lead the development and deployment of a space weather constellation mission architecture to dramatically improve the power, relevance, and resilience of the space weather data that the nation relies on. This constellation is:

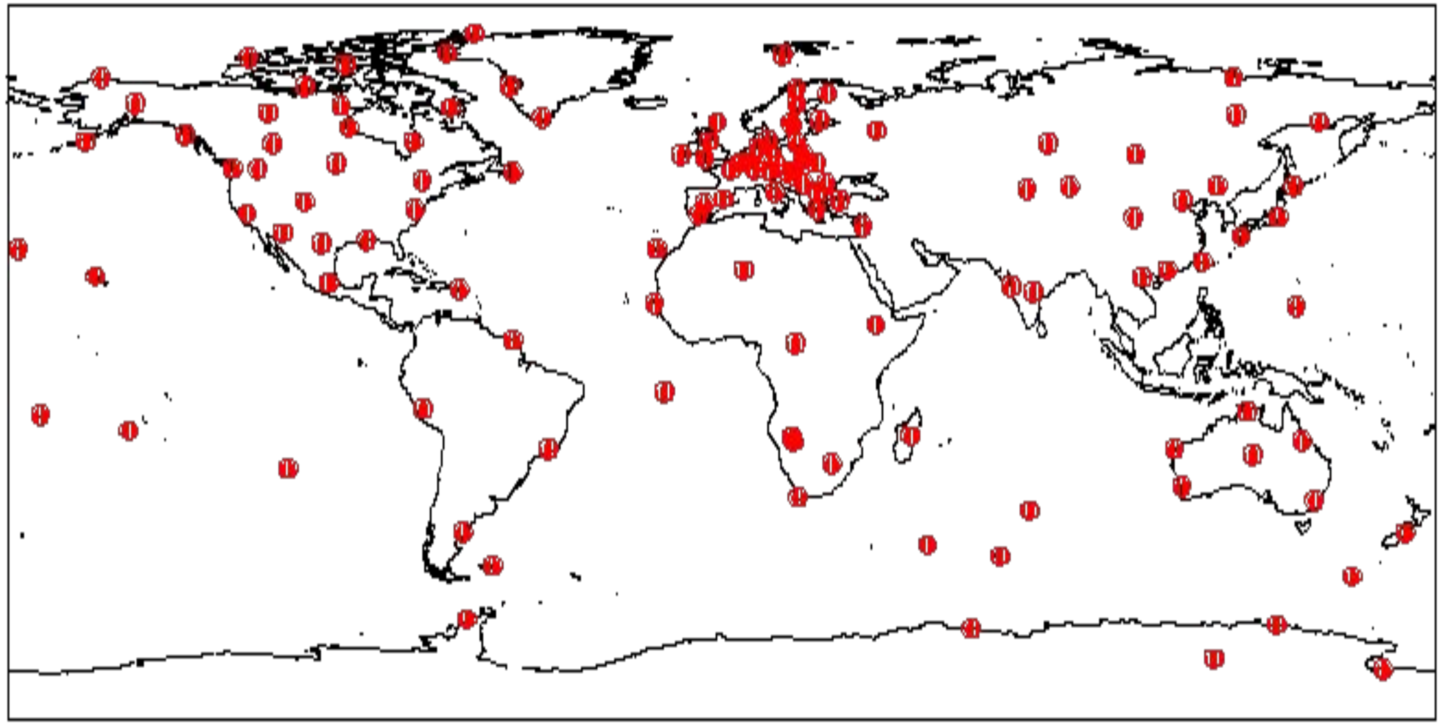
- **Global**: Using 6 small spacecraft in heliocentric orbits it will provide coverage of the full sun;
- **Intelligent**: With robust on-board computing hardware and on-board machine learning and computer vision algorithms;
- **Flexible**: Using rideshare launches and modular subsystems, it can be refreshed and deployed throughout the solar system;
- **Integrated:** Uses existing data pipelines and state-of-art numerical models to extend our understanding of CMEs, SEPs, and flares.

Paul Boerner *Neal Hurlburt*
Paul.Boerner@lmco.com *Neal.hurlburt@lmco.com*
Lockheed Martin Advanced Technology Center

INTERMAGNET (www.intermagnet.org)

Jeff Love

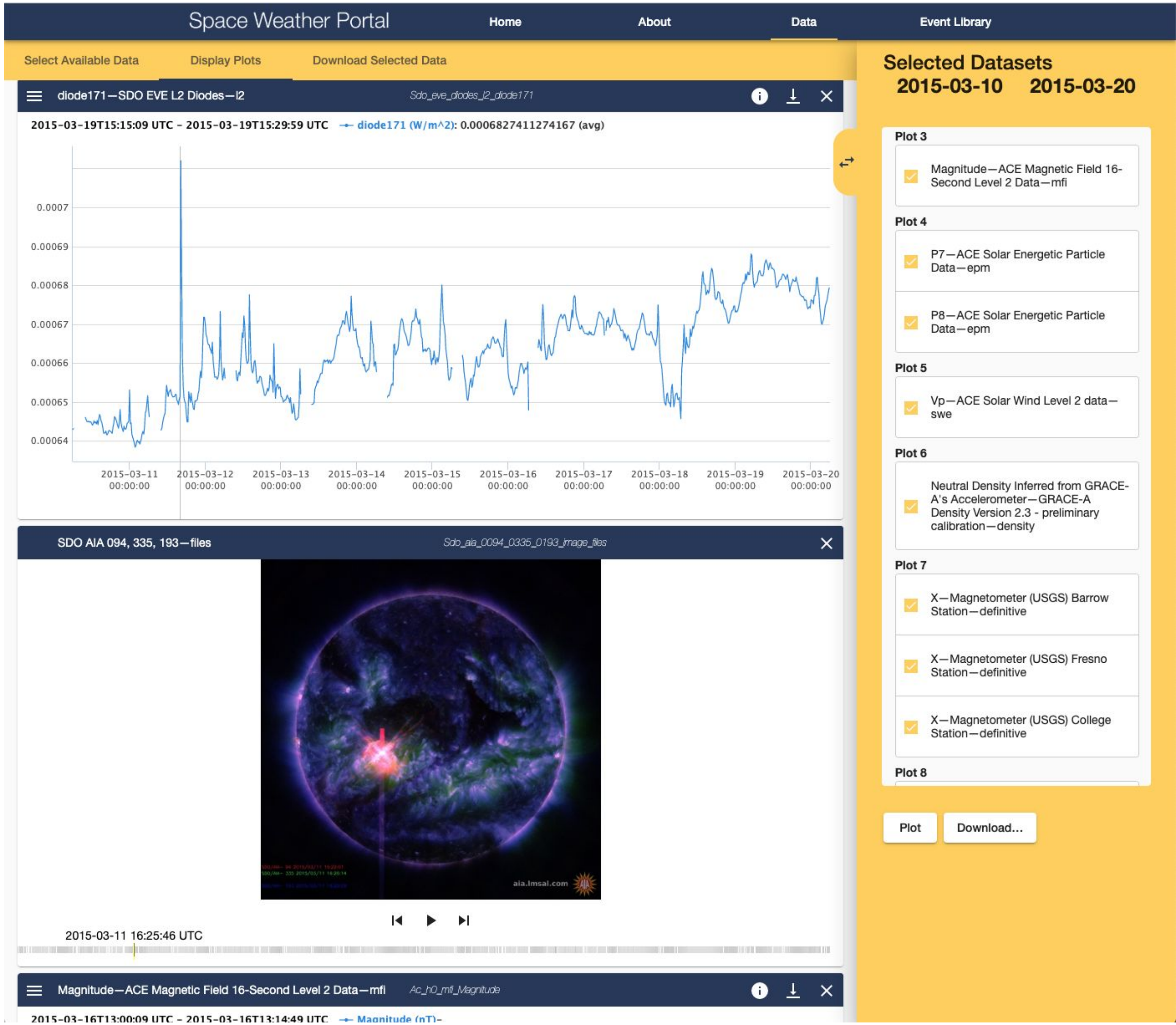
- Organization within the International Association of Geomagnetism and Aeronomy
- Voluntary consortium of observatory institutes
- Modern operational standards, checks data quality, organizes data, website
- Certified data since 1991 --- almost three solar cycles!
- All observatories produce 1-minute data. Approx. 60 produce 1-second data.
- Many institutes are real-time
- Supports:
  - Space-weather monitoring
  - Induction-hazard assessment
  - Main-field mapping
  - Aeromagnetic surveys
  - Magnetic indices
  - Solid-Earth geophysics
  - Space physics



Love, J. J., Chulliat, A., 2013.
An international network of magnetic observatories, Eos, 94(42), 373-374, doi:10.1002/2013EO420001.

Swx TREC Space Weather Data Portal

- Status
  - Event focused functioning prototype
  - https://lasp.colorado.edu/space-weather-portal
  - Improving/Adding functionality based on SME and User input
  - Event Library
  - Seeking opportunities for funding
  - Adding datasets is easy!



Public Comments

- Thomas Berger
  - Broadband communications satellites in LEO should be listed as a national critical infrastructure element.
- Paul O'Brien
  - With POES ending soon, how will the US maintain provision of timely LEO energetic charged particle data?
- Mike Wiltberger
  - Interested in hearing more about how ground based observations will be modernized in brought into operations.
- Sam Visner
  - How can the private sector make know its equities and contributions to the space weather discipline?
- Jeff Love
  - I am interested to know about SWAG views on promoting openness of data related to SW impacts on commercial operations.

Committee Discussion

- Issues and recommendations from today's talks
- Preview of tomorrow
- Overnight assignments

ADJOURN DAY 2

Day 3 begins at 9am ET, Friday, 20 Jan 2023

DAY 3
9:00 AM - 12:00 PM ET

Welcome!

- In accordance with section 60601 of the PROSWIFT Act - NOAA established the SWAG to advise the White House SWORM Interagency Subcommittee

- All 15 non-governmental representatives of the SWAG, were appointed by the SWORM Subcommittee with 3-year terms beginning on October 1, 2021

- Each SWAG member here today serves as a representative member to provide stakeholder advice reflecting the views of the entity or interest group they are representing. The PROSWIFT Act directs SWAG members to receive advice from the academic community, the commercial space weather sector, and space weather end users that will inform the interests and work of the SWORM

Roll Call

SWAG Nongovernmental End-User Representatives

Tamara Dickinson, SWAG Chair
Science Matters Consulting

Mark Olson
North American Electric Reliability Corporation

Michael Stills
United Airlines (retired)

Craig Fugate
One Concern

Rebecca Bishop
Aerospace Corp.

SWAG Commercial Sector Representatives

Jennifer Gannon
Computational Physics, Inc.

Conrad Lautenbacher
GeoOptics, Inc.

Seth Jonas
Lockheed Martin

Kent Tobiska
Space Environment Technologies

Nicole Duncan
Ball Aerospace

SWAG Academic Community Representatives

Tamas Gombosi
University of Michigan, Ann Arbor

Delores Knipp
University of Colorado, Boulder

Scott McIntosh
National Centers for Atmospheric Research

Heather Elliott
Southwest Research Institute

George Ho
Johns Hopkins University Applied Physics Laboratory

Recap of Day 1

- Welcome and Recap of Meeting 3
- Progress Since Meeting 3
- NOAA Administrator Remarks
- SWORM Co-Chair remarks
- Roundtable and Council Updates
- Current Status of Implementing the National Space Weather Strategy and Action Plan
- Session 1.1 Observational Data and Access (Ground Based)
- Session 1.2 Economic Assessment
- Committee Discussion
- Closing Remarks

Recap Day 2

- Welcome and Recap of Day 1
- Session 2.1: *Observational Data, Access, and Infrastructure in Space*
- Session 2.2: *Benchmarks, Metrics, and Scales*
- Session 2.3: *Data Infrastructure and Methods*
- Session 2.4: *Evolving Infrastructure Systems and Services*
- Session 2.5: *Industry and Government collaboration, Coordination, Outreach, and Communications in Space Weather*
- Public Comments
- Committee Discussion

Agenda Day 3

- Welcome and Recap of Day 2
- Committee Discussion
  - Recommendations
  - Writing Assignments
  - Next Steps and Timeline
- Closing Remarks
- Adjourn the Meeting

Recommendations

- ADD HERE BEFORE DAY 3
  Pull from Google doc

1.1 Recommendations - Ground-based systems

NEED FUNDAMENTAL PARADIGM CHANGES

WPG = NWS-SAP White Paper Gap

1. Recognize the importance of near-surface and ground-based sensors in operational space weather. (*WPG 2.2*)
2. A prioritization of critical systems is needed, starting with data that NOAA is using already. (*WPG 1.3, 1.6, 2.2, 2.6*)
3. There needs to be a pathway between research and operational instruments (transition to long-term operations). (*WPG 2.2*)
4. Maintenance/transition funding is the roadblock. (*WPG 2.2*)
5. Look at different funding models for data (grants, data buys). (*WPG 2.2*)
6. Improve data access, standards, and **usability**. (*WPG 1.1, 1.8, 2.8/2.10*)

1.2 Economic assessment

1. Evaluate the use of proxies and analogies (hazards or other events) to inform economic assessments of space weather *(WPG 1.3, 1.5 (3.1/3.5))*
2. Include/Add economic assessments of space weather beyond the worst case–what are thresholds of operational concern that are important to consider *(WPG 1.3, 1.5 (3.1/3.5))*
3. Emphasize the importance of and challenges in completing economic assessments *(WPG 1.3, 1.5 (3.1/3.5))*
4. Need more economists looking at this issue
5. Cost of mitigation - operations, costs and contracts, “not getting it right” *(WPG 1.4)*
6. Support the SWORM recommendation to modify WPG 1.5b
7. Societal benefit assessment for space weather forecasting, mitigation, etc.*(WPG 1.3, 1.5 (3.1/3.5))*
8. Space environment assessments establishment (ongoing standing Group/committee (e.g., SEIGE))
9. Evaluate/integrate benchmarks to inform economics assessment and vice versa.

2.1 Observational Data, Access, and Infrastructure in Space

Co-Chairs: Nicole Duncan (Ball Aerospace) and Heather Elliott (SWRI)

1. In-space infrastructure needs SWx data to be 1) organized into a central portal, 2) in standardized formats and documentation, 3) expanded to orbits of national interest (LEO, MEO, GEO, Moon and Mars), 4) compiled into relevant databases (like CMEs and anomalies) and 5) consistently available *(WPG 1.3, 2.9)*
2. How SWx research, application and operations gaps are determined, prioritized, and refreshed needs to be codified *(WPG ?)*
3. The conflict between rapidly changing SWx operation/application needs and longer Decadal timescales complicate prioritization needs to be solved *(WPG 1.6)*.
4. Adequately addressing SWx gaps (to connect systems-of-systems, address multiscale mesoscale/global processes, access key vantage points, improve modeling/forecast) requires updated approaches to mission formulation (e.g. R2O traceability, O2R feedback, pathfinder missions, model-based decision-making, incorporating Observing System Simulation Experiments (OSSEs) early and often, increased domestic and international coordination, ground/space coordination, transition funding, data standardization, operational data links) *(WPG 2.4)*
5. Prioritize SWx science and user needs - by flying additional and include low-cost and/or COTS as well as miniaturized high heritage standardized instruments to provide consistent datasets and fill key coverage gaps. *(WPG 1.6, 2.1)*.

2.1 Observational Data, Access, and Infrastructure in Space

Co-Chairs: Nicole Duncan (Ball Aerospace) and Heather Elliott (SWRI)

6. Have standard common Observing System Simulation Experiments (OSSEs) open developed by experts.
7. Gaps in the solar and coronal coverage (longitudinal, latitudinal, and regions e.g. middle coronal) need to be addressed because this impacts the accuracy and lead-time of all the space weather forecasts.
8. Maintaining well documented databases enables the effective use of historical observations to help fill in gaps in current coverage empirically.
9. With the increasing amount of observations, we need automated techniques such as leverage machine learning, cloud computing, artificial intelligence, data mining. This will require interdisciplinary research with experts in this area and puts new demands on training of our workforce.
10. The recent cycle 24 was a mild cycle with a limited number of extreme weather events in the data sets. This hinders many automated empirical forecasting techniques. *Mitigation strategies and plans to rapidly update models and forecasting techniques need to be in place for when a more active solar cycle occurs*..
11. *For critical measurements redundancy of observations or backup estimates/proxies are necessary for operational usage.* This drives the need for a pipeline of backup instrumentation providing critical observations to be ready for deployment. Additionally there are staffing demands for such critical observations because only 1 or 2 experts may have specific critical knowledge.

2.2 Benchmarks, Metrics, and Scales

Co-Chairs: Kent Tobiska (SET), Craig Fugate (former FEMA), and Mike Stills (retired UA)

Reconciliation between SWORM and Industry is needed for managing space weather risks using benchmarks, metrics, and scales (*WPG 1.1, 1.8*)

1. Main point: Benchmarks, metrics, and scales should be express[illegible]n terms and parameters that end users can apply to assessing vulnerability or taking operating actions
   - Incorporate examples of industry benchmarks that[illegible]e releva[illegible]o SWORM benchmarks, including electric power (TPL-007), USSF neutral density HASDM/CHAMP/GRACE[illegible]nd recent a[illegible]tion ICAO SpWx SARPS (?); these give baselines for improvement
   - A convergence and evolution of the SWORM ben[illegible]rks and NOAA scales should include the latest research and knowledge
2. Possible Recommendation: Focus on near Eart[illegible]omain fo[illegible]ale and metrics; be consistent throughout all applications.
   - Selecting a single domain to define me[illegible]les do[illegible]not necessarily work because of diverse needs of user sectors.
   - Solar scale/metric needs to be utilized [illegible] fore[illegible]rs/SMEs to inform the near Earth domain scale/metrics.
3. Possible recommendation: Move sc[illegible]om b[illegible]ased on the driver to being based on specific response (impacts) that will help decision-making by user commu[illegible] Exa[illegible]ples fo[illegible]ow:
   - FAA regulatory operatio[illegible]limit[illegible]arriers[illegible]ust be able talk to operations within 4 minutes (121.99)
   - Ops spec (B55) – provides[illegible]o fly routes based on passenger protection, solar activity, and communication
   - There is a standa[illegible]creat[illegible]NAT tracks – the "school of fish" on NAT which needs coordination. Pilots want to know worst case radiation[illegible]nari[illegible]g., [illegible]at's my risk?" Agencies may help with ALARA education and data validation.
   - Internationa[illegible]erators [illegible]nduc[illegible]g commerce have to consider how to minimize fuel use for efficiency and input to carbon environment – [illegible]e there [illegible]commendations?
4. Possible recommendati[illegible]diffe[illegible]t de facto surrogates that are used in the community might be tied to scales: for example, V/km (index) needed by Power [illegible]dustry; Dst (index), F10 (proxy), S10 (index), M10 (index), Y10 (index), Ap (index) needed by neutral density; AE (index) neede[illegible]for radiation belt specification; TEC (index) needed by ionospheric community; TBD (D-index for radiation?) needed by aviation community.

2.3 Data Infrastructure and Methods

Co-Chairs: Jenn Gannon (CPI) and Tamas Gombosi (UMich)

1. Space Force needs to coordinate with NOAA their SWx models, data sources and operations. *(WPG 2.2, 2.8, 3.3)*
2. There is a need for specially trained SWx data scientists/software engineers who can help to design, maintain and efficiently use SWx cyberinfratsructure. *(WPG 1.3/1.4, 2.4,2.5, 2.7, 2.8)*
3. AI/ML methods have an important role in future SWx models, but they can not replace physics based models for extreme events. Interpretable ML models must be developed.("AI/ML will happen no matter what", but having the "SME-in-the loop" is critical) *(WPG 2.5, 2.7)*

2.4 Evolving Infrastructure Systems and Services

Co-Chairs: Seth Jonas (Lockheed) and Mark Olson (NERC)

1. Continue to engage international and commercial partners in overcoming obstacles to effective Space Situational Awareness (SSA), with focus on efficient dialog and system compatibility. *(WPG 2.10)*
2. Unified space weather (or space environment) information database
3. SWORM should engage end users to focus vulnerability assessments on emerging space weather risks to key critical infrastructures that are rapidly evolving, including the changing electric power grid, space traffic management, and space based communications (e.g., satellite mesh networks). *(WPG 1.2, 1.4)*
4. Additionally, as interdependencies among many infrastructures are growing, capabilities for evaluating cascading risk scenarios should be pursued. *(WPG 1.2, 1.4)*
5. The Space Weather Strategy should be updated to reflect the multipoint solar observation, solar polar mission, data acquisition and availability, and modeling needs to support plans for (human and robotic) space exploration and space commerce.

2.5 Industry and Government Collaborations, Coordination, Outreach, and Communications on Space Weather

Co-Chairs: Rebecca Bishop (Aerospace Corp) and Scott McIntosh (UCAR)

1. Promote the use of exercises (eg., table top) for improving coordination, outreach and communications (*WPG 2.7, 2.9, 2.11, 3.1-3.3*)
2. Promote a concept such as the Space ISAC Watch Center or increase purview and stakeholders of SPACE ISAC. (*WPG 3.1, 3.3*)
3. Emphasize industry/government interaction outside of well-established industries. Utilize lessons and collaboration/coordination structure developed by these industries (e.g., power grid) (*WPG 3.3*)

Misc Recommendations (Open Public Session, etc)

1. We need to fund the transition from research to operations particularly the final stages to become operational.
2. Encourage NOAA to increase engagement, prioritization, and investment on space weather to align it with their identification of SWx as one of six priority areas
3. International engagement and coordination
4. National security annex
   a. Risk assessment, workforce, etc.
5. Broaden and augment community and stakeholder engagement (**public**, local government, etc)

White Paper Implementation Gap Summary – Obj 1 (1of2)

1.1 Refine benchmarks: “...1) coordinating activities and identifying funding mechanisms to support research efforts that will inform the benchmarks, 2) additional communication and collaboration with stakeholders in industry and end users who are impacted by space weather phenomena, and 3) raising awareness for the importance of investments in space weather observation and monitoring capabilities needed for sustained, long-term improvement of the space weather benchmarks.“

1.2 Vulnerability and risk management of critical infrastructure: “...Space weather vulnerability assessments should highlight interdependencies between sectors to better predict potential secondary impacts and cascading failures“ & “Previous power grid vulnerability assessments may not have considered the full 3D effects of Earth conductivity structures and USGS’s recent efforts are likely the first attempts to appropriately leverage Magnetotelluric (MT) data and associated research to inform vulnerability

1.3 Model the *effects* of space weather on national critical functions & infrastructure: a) “Denser-geographic and broad-band (higher-frequency) magnetotelluric surveys in high-risk areas, especially in the Eastern United States and the upper Midwest.” b) ”Expansion of the USGS ground-based magnetometer observatory network, to reduce uncertainties in geoelectric hazard maps.” c) “Magnetotelluric surveying in areas of Canada where there are significant interdependencies between US and Canadian electric infrastructure.” d) “Develop one or more standardized time related geomagnetic field waveforms that will provide a consistent means for evaluating the impacts of geomagnetic storms.” e) “Increase the capabilities of modeling tools relevant to GMDs to ensure Geomagnetically-induced current (GIC) threat calculations can be conducted.”

White Paper Implementation Gap Summary - Obj.1 (2of2)

1.4 Identify and assess the effects on operations and missions: "The data is owned by industry and would not be available to the research community unless it is voluntarily given. Additional gaps will be assessed upon completion of action 1.2 and 1.3."

1.5 Assess the cost: "Space weather events range in intensity and duration and impacts between sectors vary. Such inconsistencies are not necessarily problematic but it should be further quantified with future efforts."

1.6 Identify and Prioritize R&D: "Gaps remain around testbed activities, including information sharing and the need to keep pace with the rapid turnover in commercial infrastructure."

1.7 Test, evaluate, and deploy technologies and devices to mitigate the effects: "Other relevant sectors should be added to the work DOE has done to help mitigate risk to the Energy Sector."

1.8 Support the development and use of standards: "While the existing standards improve the resilience of the energy sector to GMD impacts, the standards are only effective if they are adopted. Future efforts may need to focus on facilitating mitigation efforts and driving standards adoption"

White Paper Implementation Gap Summary - Obj.2 (1of2)

2.1 Identify baseline operational observation capabilities: "Need to obtain more quantitative and objective assessments of observational coverage and identification of gaps. NOAA is in the process of conducting Observing System Simulation Experiments (OSSEs). As new information is obtained, the priorities identified in this report must be reassessed."

2.2 Ensure baseline operational platforms, capabilities, and networks: "Policies need to be developed to facilitate the transition of research and academic data collection platforms to agencies responsible for long-term operational monitoring."

2.3 Support and coordinate opportunities for fundamental research: " Space-based monitoring projects and exploratory missions need to be coordinated with agencies responsible for ground-based monitoring."

2.4 Identify, develop, and test innovative approaches to enable enhanced, more informative, robust, and cost-effective measurements.: A summary of gaps can be found in the NAS workshop proceedings identified in Actions 2.1 and 2.3

2.5 Enhance current space weather models and develop improved techniques: "The space weather community has requested access to observational and operational data streams as the simulation output will contribute to the identification, separation, maintenance and augmentation of high-quality datasets for assimilation, model validation, and to optimize utilization. The model output is critical to baseline current model capabilities and will allow for model developers and researchers to identify and demonstrate improvements."

White Paper Implementation Gap Summary - Obj.2 (2of2)

2.6 Identify and release, as appropriate, new or previously underutilized data sets: “None identified”

2.7 Identify mechanisms for transitioning model/observation R2O: “A space weather prediction testbed at SWPC is critical for a successful R2O2R process and the transition of models into operations and to get operational needs back to the research community.”

2.8 Enhance accessibility and sharing of observational data: “The broad scientific and engineering communities within the space-weather enterprise would benefit from the free and open exchange of data related to the impacts of space weather on technological systems operated by the commercial, academic, and governmental sectors.”

2.9 Improve notification effectiveness: “The space weather forecasts need to be provided with sufficient lead time and fidelity to be useful by many owners of Critical Infrastructure.”

2.10 Engage International Partners to ensure global Space Weather products: “Meaningful collaborations, and (possibly) the exchange of modest amounts of financial support, with foreign geophysical agencies could facilitate acquisition of real-time global monitoring data ofinterest to the U.S. domestic space weather community.” (Combined with 2.8)

2.11 Develop and refine situational awareness capabilities: “None Identified”

White Paper Implementation Gap Summary - Obj.3 (1of1)

3.1 Develop, review, and update Federal response plans, programs, and procedures to address the effects of space weather: “None Identified”

3.2 Develop and disseminate products and information on the effects of space weather that support coordinated response and recovery efforts: “None Identified”

3.3 Facilitate information sharing: “Efforts to create a satellite-anomaly attribution information system also fall under this action. … Minimal progress was made in this area largely because of the concerns of proprietary information from satellite owners. An international effort is still underway in the Coordination Group for Meteorological Satellites (an international group of government entities that coordinates meteorological satellite systems globally)”.

3.4 Assess executive and statutory authority regarding the ability to direct, suspend, or control critical infrastructure operations, functions, and services before, during, and after space weather events: “None Identified”

3.5 Exercise Federal response, recovery, and operations plans and procedures for space weather events: “These exercises have served to enhance awareness and improve preparedness for space weather, but much still needs to happen, especially at state and local levels to ensure risks associated with space weather are well understood and addressed.”

BREAK

10:15 - 10:30 AM ET

Closing Remarks

Space Weather Workshop

Adjourned

Thank you!

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