



Space Weather Policy - Building the Nation's Resilience Against Space Weather Storms



Dr. Jennifer "Jinni" Meehan

National Space Weather Program Manager

National Weather Service

National Oceanic and Atmospheric Administration

Executive Secretary

White House Space Weather Subcommittee - SWORM

Designated Federal Officer

PROSWIFT Act Directed Space Weather Advisory Group



Bill Murtagh

Program Coordinator

Space Weather Prediction Center

National Weather Service

National Oceanic and Atmospheric Administration

***Safeguarding Society with
Actionable Space Weather Information***

What is Space Weather?

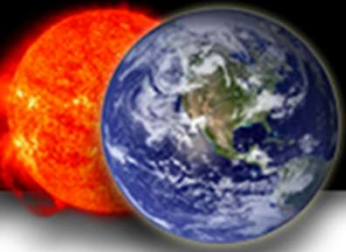
Space weather refers to the variable conditions on the Sun and in space that can influence performance and reliability of space and ground-based technological systems, and endanger life or health.

Coronal
Mass
Ejection

Ionosphere

Magnetosphere

Various emissions from the Sun affect
Earth
93 Million Miles from Sun to Earth



Notable Space Weather Events

Carrington Event, 1-2 September 1859:

Most significant event on record. Telegraph system world-wide impacted. Aurora visible in Central America.

Hydro-Quebec Storm, 14 March 1989:

Power blackout in Montreal and entire province of Quebec.

Severely damaged New Jersey transformers. Numerous U.S. grid anomalies.

Operation Anaconda, Afghanistan, 4 March 2002:

Three U.S. soldiers killed - space weather disrupted satellite communications.

Halloween Storms, October 2003:

Power grid outage in Malmo, Sweden; damage to South Africa grid; Japan loses satellite.

Near Miss, 23 July 2012:

"Century class" event, but the eruption site was on far side of the Sun and missed Earth.

SpaceX Starlink Loss, 3 February 2022:

Loss of 38 of 49 satellites due to increased drag induced by a minor geomagnetic storm.





Space Weather Impacts

Infrastructure and Activities Vital to National Security and the Economy

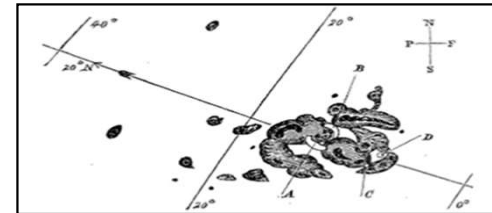
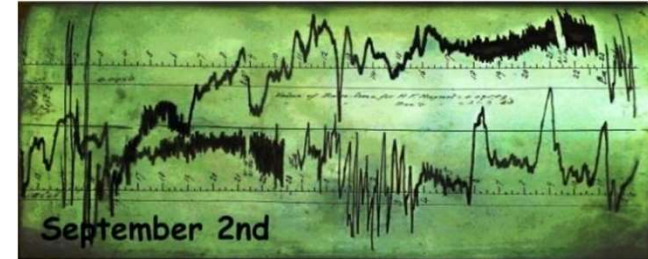


Space weather-induced electricity blackout: Daily domestic economic loss in the U.S. = \$41.5 billion plus an additional \$7 billion loss through the international supply chain.

Quantifying the daily economic impact of extreme space weather due to failure in electricity transmission infrastructure, Centre for Risk Studies, University of Cambridge, Jan 2017

Motivation for National Policy

- Reliance on technology vulnerable to space weather
- Improved understanding of extreme space weather
- Relatively high probability of an extreme space weather event
- Space weather events with significant impacts have occurred

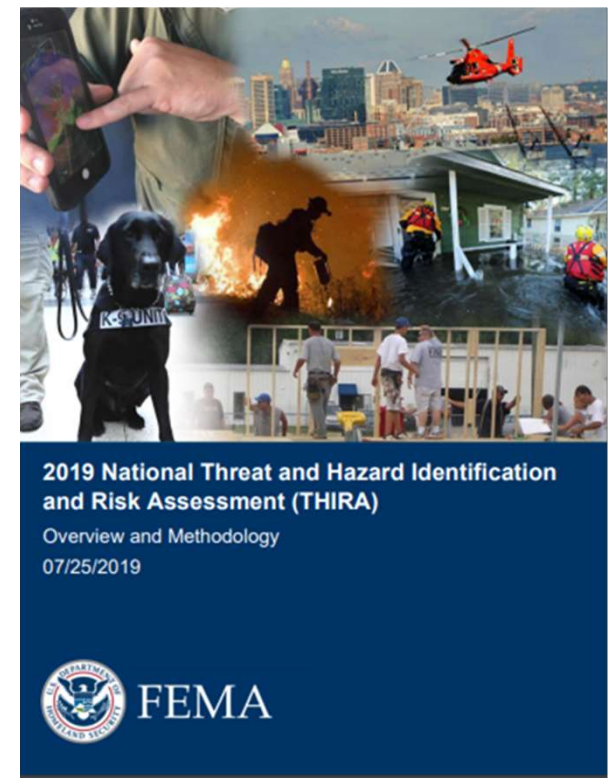


A Global Threat - National Policy

July 2019 - FEMA National Threat and Hazard Identification and Risk Assessment (THIRA)

Table 1: Threats and Hazards of Concern Identified for the 2019 National THIRA^{8,9}

Threat/Hazard Type	Threat/Hazard	Area/Region
Natural	Plausible Concurrent Operations ¹⁰	Nationwide
	Earthquake	Washington, Oregon, California, Idaho 600,000 sq. km in the Midwest/East Galveston, Texas to the Midwest
	Hurricane	Fort Lauderdale, Florida to Alabama Hawaii
	Pandemic	Nationwide
	Space Weather	Nationwide



NATIONAL WEATHER SERVICE

Space Weather Policy & Requirements Drivers

PROSWIFT (Public Law No: 116-181)

- Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act
 - Space Weather Advisory Group
 - NAS Roundtable

Executive Order 13744 (2016), 13865 (2019)

- Coordinating Efforts To Prepare the Nation for Space Weather Events
- Coordinating National Resilience to Electromagnetic Pulses

OSTP SWORM Subcommittee

- Space Weather Operations, Research, and Mitigation Interagency Subcommittee
- 34 Departments, Agencies, and Offices
- National Space Weather Strategy and Action Plan

National Space Council

- U.S. Space Priorities Framework

Space Policy Directive-3

- National Space Traffic Management

NASA-NOAA Agreement

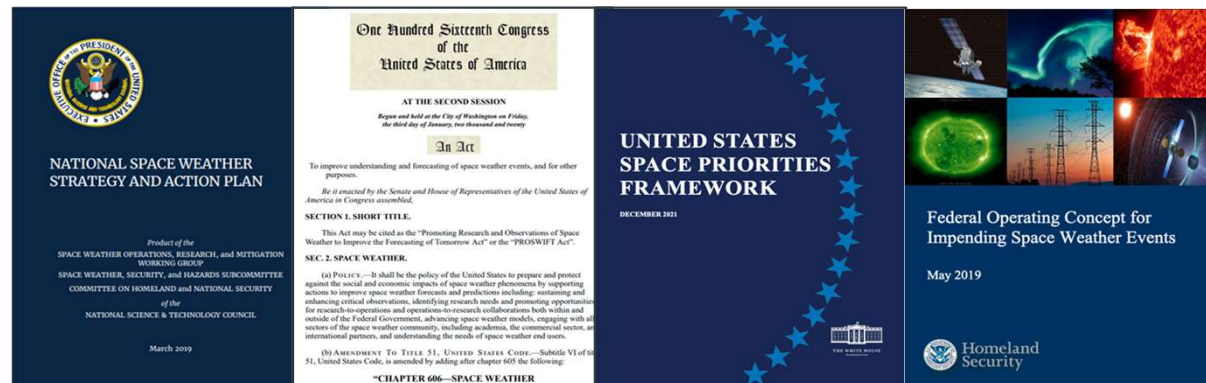
- Interagency Agreement for Human Spaceflight Activities

NASA-NOAA-NSF-DAF Agreement

- Interagency Agreement encourage and support collaboration to advance the Nation's space weather research and operations capabilities

FEMA Federal Operating Concept

- Impending Space Weather Events



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2014-2016

National Space Weather Strategy

Tasked by the President to coordinate the implementation of a comprehensive national strategy on space weather

Nov 2014 – Space Weather Operations, Research, and Mitigation (SWORM) Task Force is established

Co-Chaired by White House Office of Science and Technology Policy, National Weather Service, and Dept. of Homeland Security

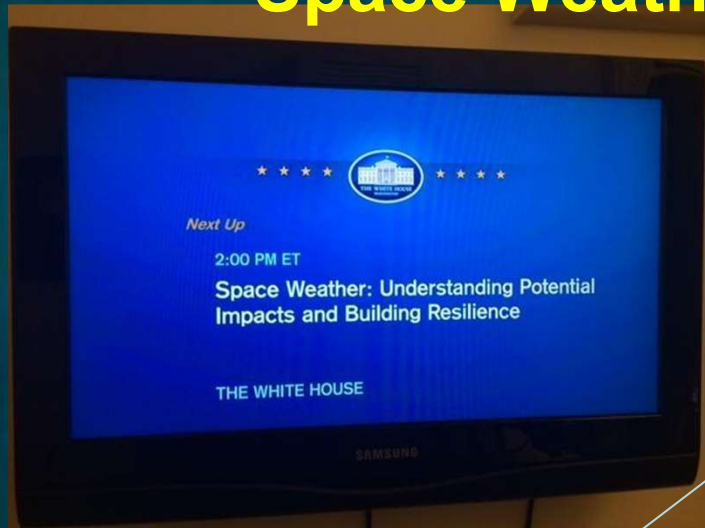
~30 federal departments and agencies



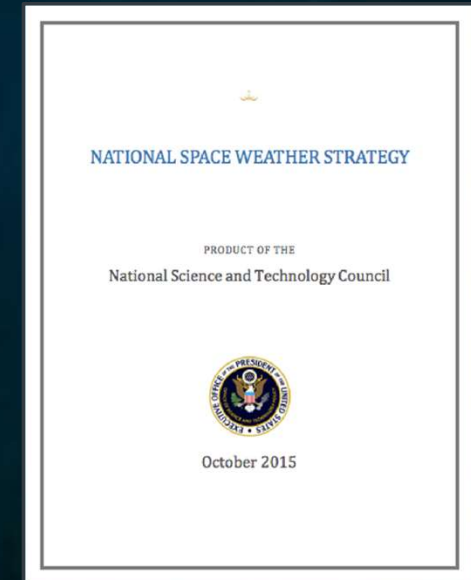
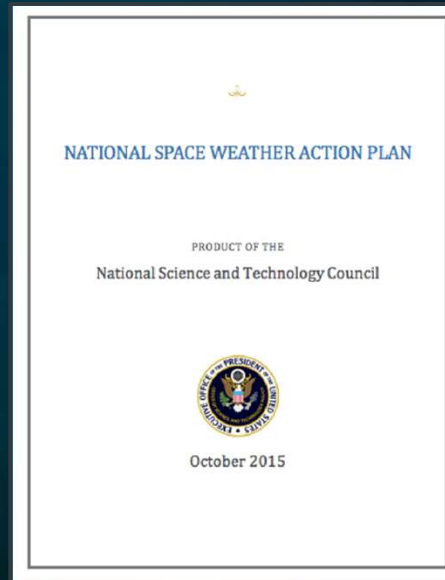
Where the sausage is made...



29 October 2015 – Release of the National Space Weather Strategy and Action Plan



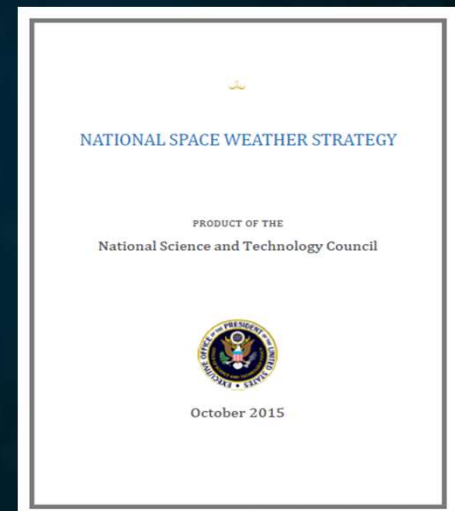
**Bill Nelson - Current
NASA Administrator**



National Space Weather Strategy – Structure

Strategy articulates six high-level goals

1. Establish Benchmarks for Space-Weather Events
2. Enhance Response and Recovery Capabilities
3. Improve Protection and Mitigation Efforts
4. Improve Assessment, Modeling, and Prediction of Impacts on Critical Infrastructure
5. Improve Space-Weather Services through Advancing Understanding and Forecasting
6. Increase International Cooperation



Nov 2015: OSTP briefs Senate Commerce Committee

Apr 2016 (114th Congress): S.2817 - Space Weather Research and Forecasting Act introduced in Senate. It included:

- Protection of Critical Infrastructure (DHS)
- Protection of National Security Assets (DOD)
- Ensuring the Safety of Civil Aviation (DOT)



Fixing America's Surface Transportation (FAST) Act (Dec 2015)

The statute authorizes the Secretary of Energy to order emergency measures, following a Presidential declaration of a grid security emergency, to protect or restore the reliability of critical electric infrastructure or defense critical electric infrastructure during the emergency.

As defined by the bill, a grid security emergency could result from a:

- physical attack
- cyber-attack using electronic communication
- electromagnetic pulse (EMP)
- **geomagnetic storm event**

Oct 2016 – Executive Order 13744: *Coordinating Efforts to Prepare the Nation for Space Weather Events*

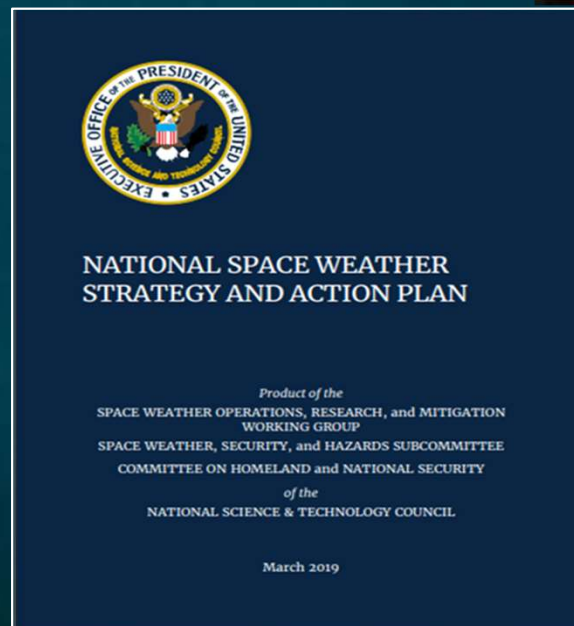
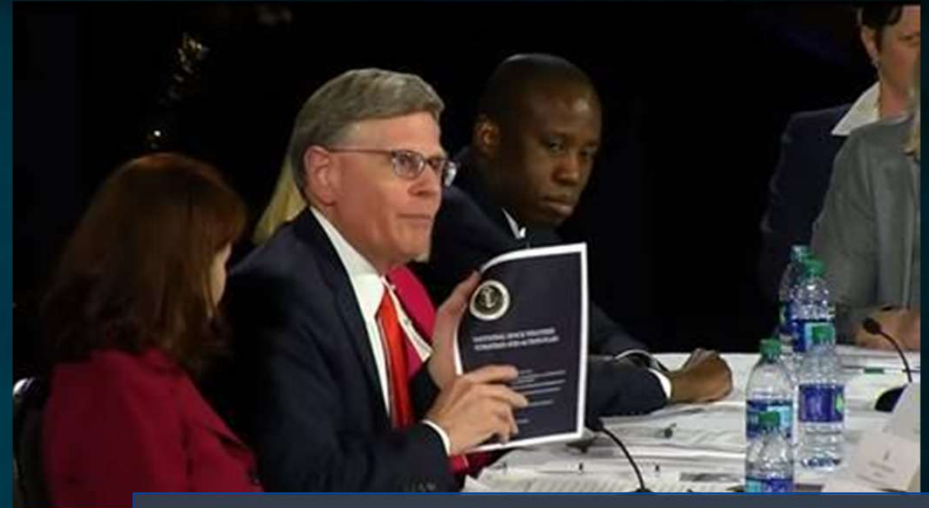
The Federal Government must have:

1. Capability to **predict and detect** a space weather event,
1. Plans and programs necessary to **alert the public** and private sectors to enable mitigating actions,
1. **Protection and mitigation** plans, protocols, and standards required to reduce risks to critical infrastructure, and
1. Ability to **respond to and recover** from the effects of space



2019 – 2020

- Update to National Space Weather Strategy and Action Plan
- Executive Order on Coordinating National Resilience to Electromagnetic Pulses



The 2019 Strategy and Action Plan seeks to achieve three objectives to enhance the Nation's resilience to space weather:

- Enhancing the **protection** of national security, homeland security, and commercial assets and operations against the effects of space weather
- **Developing and disseminating** accurate and timely space weather characterization and **forecasts**
- Establishing plans and procedures for **responding to and recovering from** space weather events



Driving towards a resilience-based outcome!



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

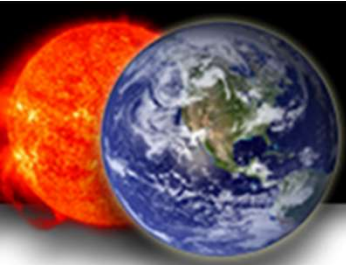
March 2019

Space policy driving space weather services

Changes in priorities from one administration to the next can create challenges

- Space Policy Directive-1: Reinvigorating America's Human Space Exploration Program (Dec 2017)
 - Space weather observations and prediction critical for space travel
- Space Policy Directive-3: National Space Traffic Management (STM) Policy (Jun 2018)
 - Timely and actionable STM services are essential for space safety and sustainability
 - The largest uncertainty in determining orbits for satellites operating in low Earth orbit is atmospheric drag which is influenced by space weather



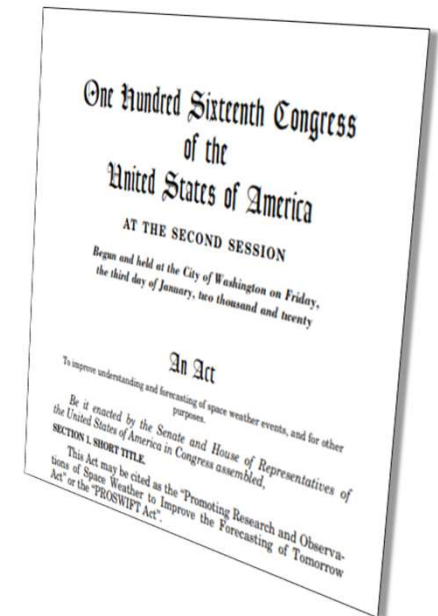


PROSWIFT Act - Overview

Passed Congress by unanimous consent - Signed by Prez on Oct 21, 2020

Basic Elements

- 60601 Space weather
 - Role of Federal Agencies
 - **Interagency Working Group (SWORM)**
 - Interagency Agreements
 - **Space Weather Advisory Group (SWAG)**
- 60602 Integrated strategy
- 60603 Sustaining and advancing critical observations
- 60604 Research activities
- 60605 Space weather data
- 60606 **Knowledge transfer and information exchange - National Academy Roundtable**
- 60607 Pilot program commercial sector
- 60608 Benchmarks



SWORM Structure



Office of Science and Technology Policy

(OSTP)

National Science and Technology Council

(NSTC)

Committee for Homeland and National Security (CHNS)

Space Weather Operations, Research, and Mitigation (SWORM) Subcommittee
Co-Chairs

OSTP, Assistant Director of Space Policy

NOAA, Assistant Administrator for Weather Services

DHS, Assistant Director, National Risk Management Center

Objective 1

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

Co-leads
DOD & DHS

Objective II

Develop and Disseminate Accurate and Timely Space Weather Characterization and Forecasts

Co-leads
DOC & NASA

Objective III

Establish Plans and Procedures for Responding to and Recovering from Space Weather Events

Co-leads
DHS & DOC



SWORM Priorities

- R2O2R framework for space weather forecasting
- Space weather events benchmarks;
- U.S. space weather scales
- Space weather hazard mapping of the United States
- Observations and forecasting support for human spaceflight
- Space weather observations and modeling to improve space traffic coordination and space situational awareness



SWORM Priorities

- Space weather observations and modeling necessary to maintain safe operations for aviation
- Response, recovery, and operations plans and procedures for space weather events across sectors and stakeholders
- Continuity of an operational satellite mission that provides coronagraph, solar wind, energetic particles, and other measurements essential to space-weather forecasting along the sun-Earth line, and seek novel space-based observations to further enhance forecasting.

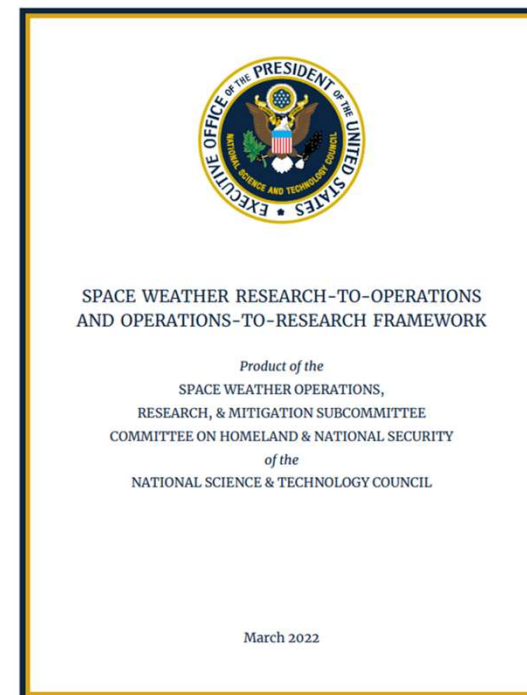


Research-to-Operations-to-Research (R2O2R) PROSWIFT §60604

- PROSWIFT directs federal agencies to develop formal mechanisms to **transition space weather research to operations**
- OSTP released Framework in March 2022

Key to a successful R2O2R process is understanding and communicating operational needs (O2R)

- NOAA and NASA will lead the Framework initiative to foster the collaborative transition of space weather capabilities from a variety of sources to include academia and commercial enterprises, into operations
 - **MOA with Government Agencies (NOAA, NASA, NSF, DAF)**
- Forecasters, researchers, and end users engage in capability evaluation and testing - Exercise/experiment



<https://www.whitehouse.gov/wp-content/uploads/2022/03/03-2022-Space-Weather-R2O2R-Framework.pdf>



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WHSR/FEMA Communications

Presidential Memo-32: Establishing Standardized Procedures for Reporting Presidential Critical Information Requirements

- The White House Situation Room is primary entry point reportable information

Senior Officials Exercise: refine strategic messaging for extreme space weather event to ensure government is prepared and speaks with one voice

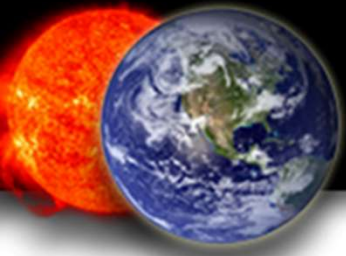
Development of National Communications Strategy underway





Space Weather Advisory Group

weather.gov/swag



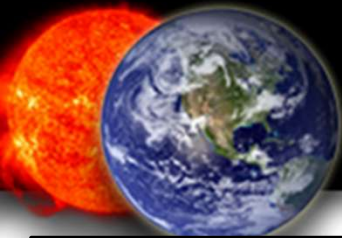
PROSWIFT Act - Space Weather Advisory Group (SWAG)

ESTABLISHED – In **2021** by **NOAA Administrator** ... informs the interests and work of **SWORM** subcommittee

COMPOSITION - **appointed by SWORM**, 5 *representatives* of **academic** , **commercial** space weather, **end user** communities

TERM LIMITS - 3 years terms, no more than 2 consecutive terms

CHAIR – chosen by NOAA Administrator, no more than 2 terms, regardless of whether the terms are consecutive



Committee Members

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 (former FEMA Adm)

Rebecca Bishop
Aerospace Corp.

SWAG Commercial Sector Representatives

Jennifer Gannon
Computational Physics, Inc.

Conrad Lautenbacher
GeoOptics, Inc. (former NOAA Adm)

Seth Jonas
Lockheed Martin

Kent Tobiska
Space Environment Technologies

Nicole Duncan
Ball Aerospace

SWAG Academic Community Representatives

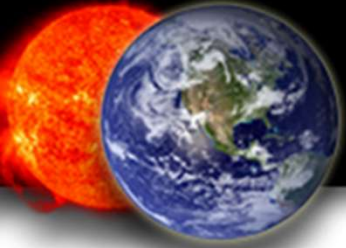
Tamas Gombosi
University of Michigan, Ann Arbor

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

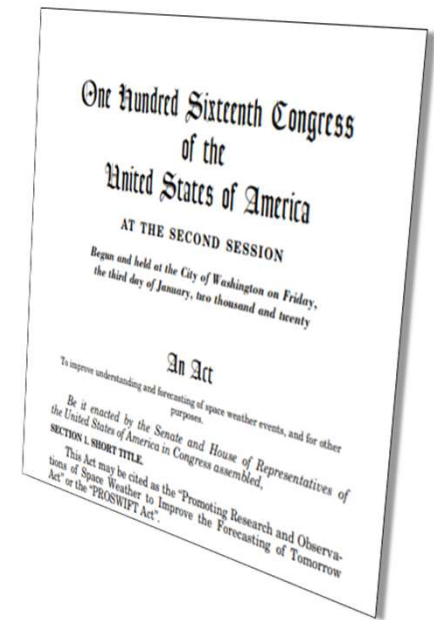


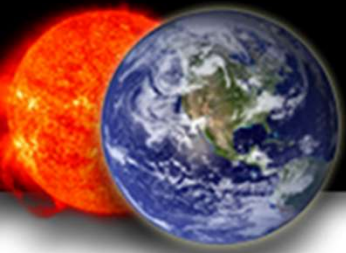
PROSWIFT Act - SWAG Duties

Advise White House SWORM Subcommittee on:

- Facilitating advances in the space weather enterprise of the US
- Improving the ability of the US to prepare for, mitigate, respond to, and recover from space weather phenomena
- Enabling the coordination and facilitation of R2O2R
- Developing and implementing the integrated strategy for coordinated observation

Conduct a comprehensive user needs survey of space weather





SWAG Meetings

December 1, 2021 (virtual)

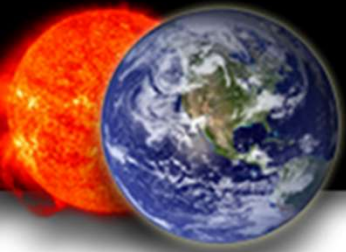
March 17-18, 2022 (virtual)

June 13-14, 2022 (virtual)

January 18-20, 2023 (in person DC)

March 20, 2023 (virtual)

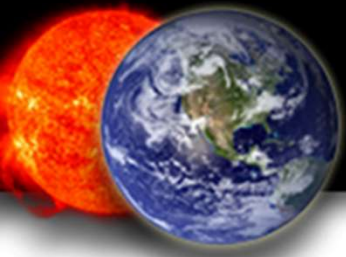




PROSWIFT Act - User Survey

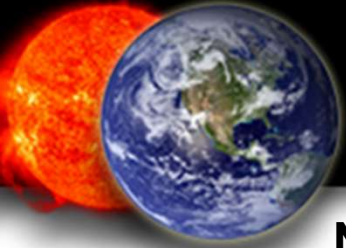
User Survey Requirements:

1. Assess the **adequacy of Federal Government goals** for lead time, accuracy, coverage, timeliness, data rate, and data quality for space weather observations and forecasting;
2. Identify options and methods to **advance the above goals**;
3. Identify **opportunities for collection of data** to address the needs of space weather users;
4. Identify methods to **increase coordination of space weather R2O2R**;
5. Identify opportunities for new technologies, research, and instrumentation to aid in understanding, monitoring, modeling, prediction, and warning of space weather; and
6. Identify methods and technologies to **improve preparedness** for space weather.



User Survey Sectors

- Electric Power Grid
- Global Navigation Satellite System
- Aviation
- Emergency Management
- SSA/STM-C
- Human space flight
- Research
- *National Security*
- *Radio Frequency Application (comms and Radar)*
- *Satellite*



Space Weather Roundtable

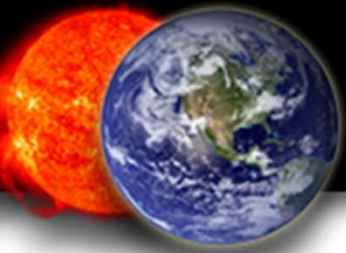
PROSWIFT § 60606

National Academies Government-Academic-Commercial Roundtable

Facilitate communication and knowledge transfer among Government participants in the SWORM, the academic community, and the commercial space weather sector

- NASA, NOAA, and NSF will fund 5 year effort and provide ex-officio members to:
 - Facilitate **advances** in space weather **prediction and forecasting**;
 - increase **coordination** of space weather **research to operations and operations to research**; and
 - improve **preparedness** for potential space weather phenomena
- First Meeting held on Oct 14, 2022

1. Geoffrey Crowley, Orion Space Solutions, Co-Chair
2. Sarah E. Gibson, National Center for Atmospheric Research,
3. Hazel Bain, Cooperative Institute for Research in Environmental Sciences, CU
4. Anthea J. Coster, MIT Haystack Observatory
5. Jennifer L. Gannon, Computational Physics Inc.
6. Janet C. Green, Space Hazards Inc.
7. Justin C. Kasper, BWX Technologies and University of Michigan
8. Delores Knipp, University of Colorado, Boulder
9. Louis J. Lanzerotti, NAE, New Jersey Institute of Technology
10. Mark H. MacAlester, Dept. of Homeland Security/CISA
11. M. Granger Morgan, NAS, Carnegie Mellon University
12. Geoffrey D. Reeves, Los Alamos National Laboratory
13. Michael Starks, Air Force Research Laboratory
14. Leonard Strachan, Jr., Naval Research Laboratory
15. Drew Turner, Johns Hopkins Univ.-Applied Physics Laboratory
16. Louis W. Uccellini, NOAA National Weather Service (ret.)
17. Shasha Zou, University of Michigan



Collaboration and Coordination

- Space Weather Advisory Group
- NASEM Space Weather Roundtable
- NASEM Heliophysics Decadal Survey
- NASA Space Weather Council

TEAMWORK

To make the dream work



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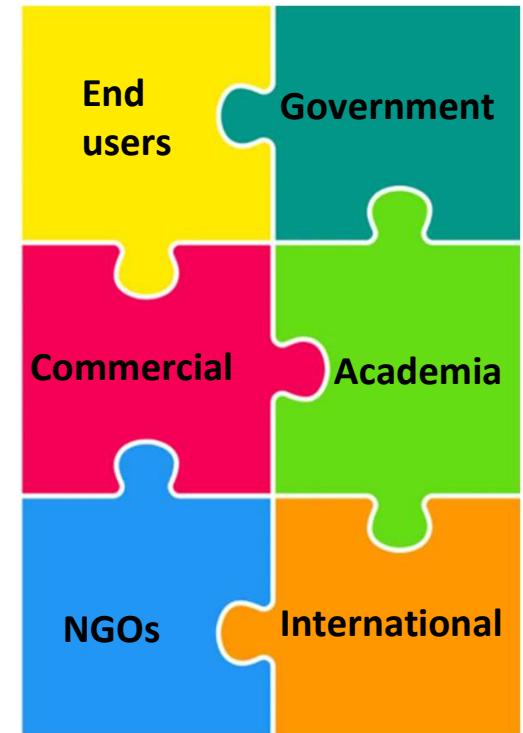
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Partnering to Improve Impact-based Decision Support Services (IDSS) and Understanding User Needs

GOAL: Provide space weather information and interpretative services to meet Core Partners' requirements to enable decision-making processes for the protection of lives and livelihood

Collaboration and coordination is key

- SWORM Subcommittee
- Space Weather Advisory Group
- National Academies Space Weather Roundtable
- National Academies Heliophysics Decadal Survey
- NASA Space Weather Council



A Space Weather-Ready Nation

Building a Nation Ready, Responsive, and Resilient to Space Weather

Maintain Critical Observations, Operationally Supportive



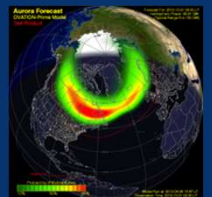
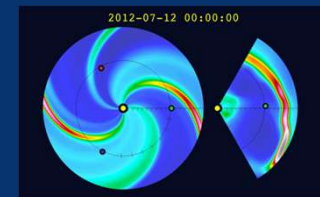
Partnerships

Involves the entire US Space Weather enterprise working together



Continued Research

Improved understanding with new modeling and R2O2R capability

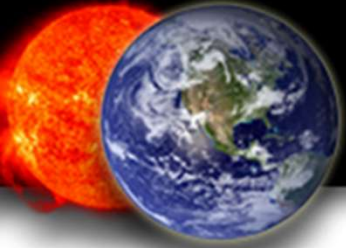


The Outcome

Better information connected to key stakeholders for better decisions - enhance National resilience



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Thank you!

weather.gov/space
spaceweather.gov
sworm.gov
weather.gov/swag

jennifer.meehan@noaa.gov
william.meehan@noaa.gov



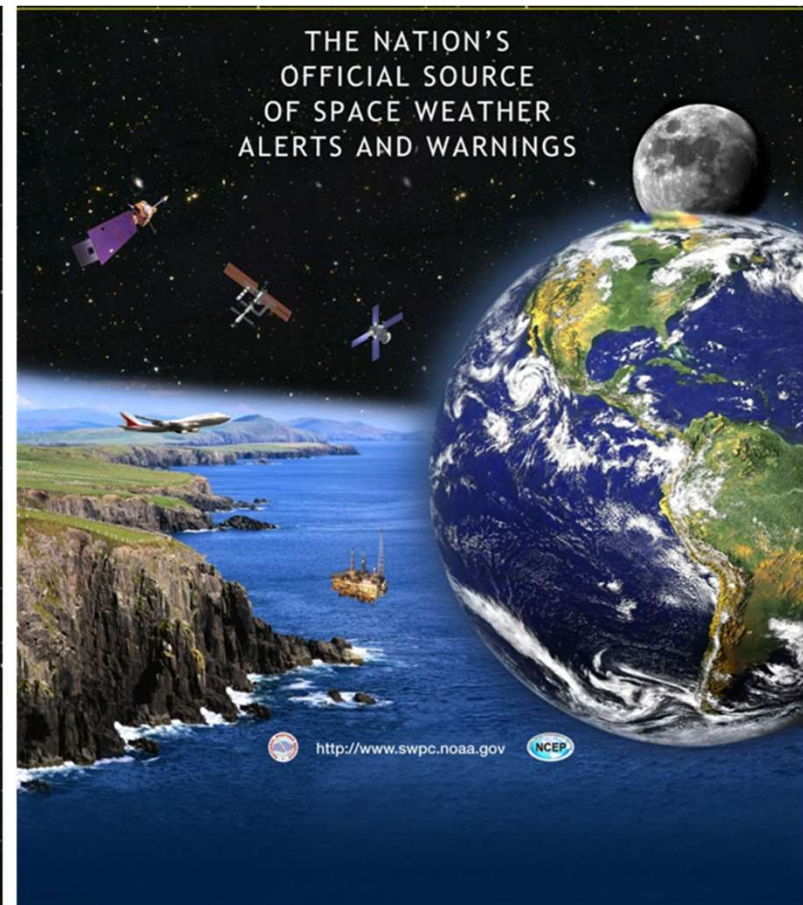
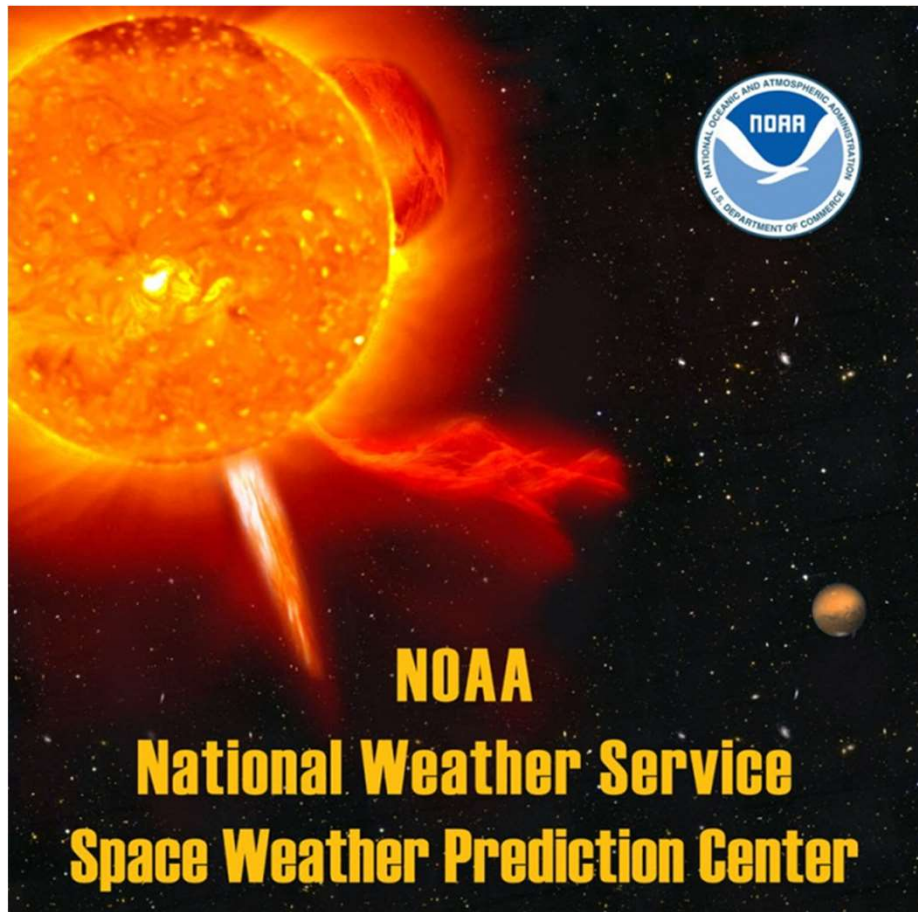
Backup Slides



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24/7 Monitoring



NATIONAL WEATHER SERVICE

SWPC's MISSION



Safeguarding society with actionable space weather information

- ☀ Safeguarding Serve others; Prevent harm, loss, or damage
- ☀ Society We first serve the Nation & We also
serve interests Globally and in Space
- ☀ Actionable Timely, Accurate, Reliable, Operational,
Consistent, Linked to Decisions, Scientifically-
Sound, Accessible
- ☀ Space Weather Information Products, Services, Forecasts.



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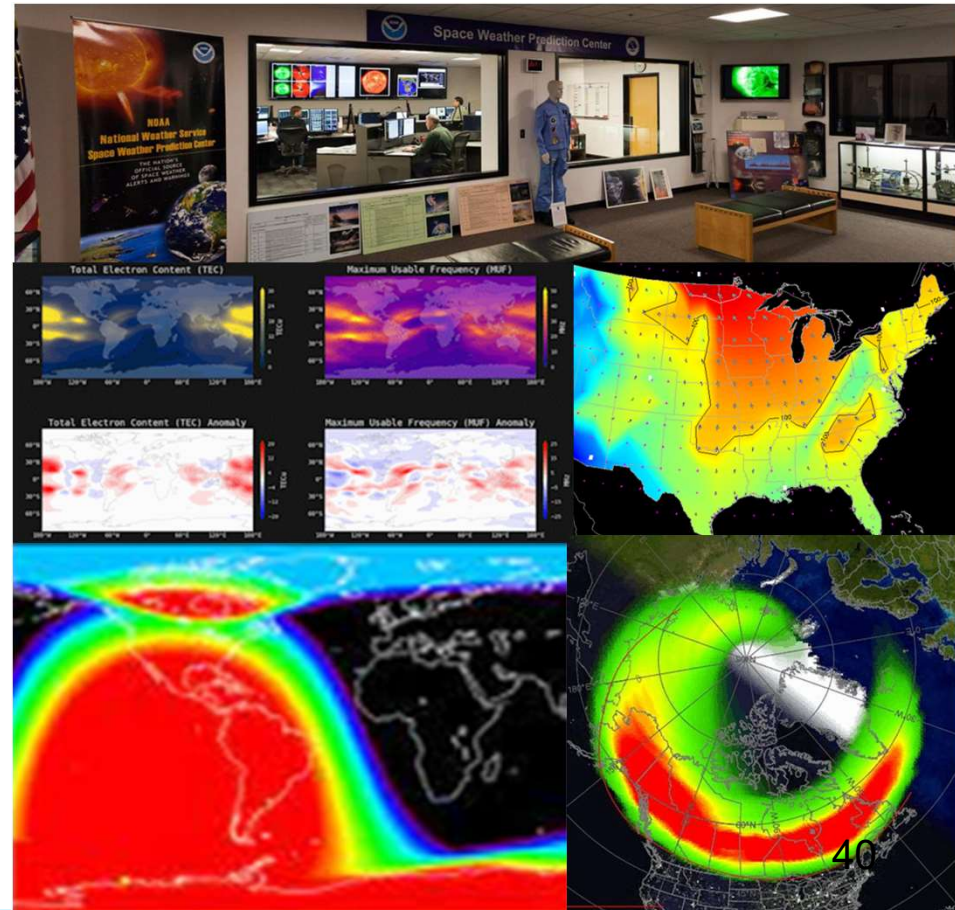
Safeguarding society with actionable space weather information

Alerts, Watches, and Warnings

NOAA Space Weather Scales:

- Geomagnetic Storms
- Solar Radiation Storms
- Solar Flare Radio Blackouts

Global provider of operational space weather models and observations for Aviation



USAF (557th Weather Wing) provides space weather services in support of DOD



NATIONAL WEATHER SERVICE

Emerging Mission Focus Areas



✈️ **Aviation**

🚀 **Human Spaceflight**

✳️ **Space Situational Awareness (SSA)**

▽ **Research-to- Operations (R2O)**



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Mission Focus Area: Aviation

OPSPEC/MSPEC B055—NORTH POLAR OPERATIONS.

FAR 121.99: the operator must have effective communications capability for all portions of the flight

The operator must take into consideration for each dispatched polar flight, the predicted solar flare activity and its effect on communication capability.

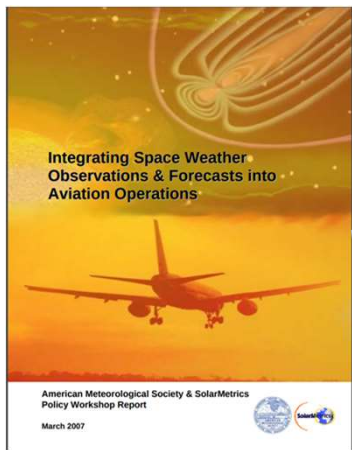
Extended Operations (ETOPS) AC No: 120-42B

(7) Crew Exposure to Radiation during Solar Flare Activity. The certificate holder must provide a plan for mitigating crew exposure to the effects of solar flare activity at the altitudes and latitudes expected in such operations.

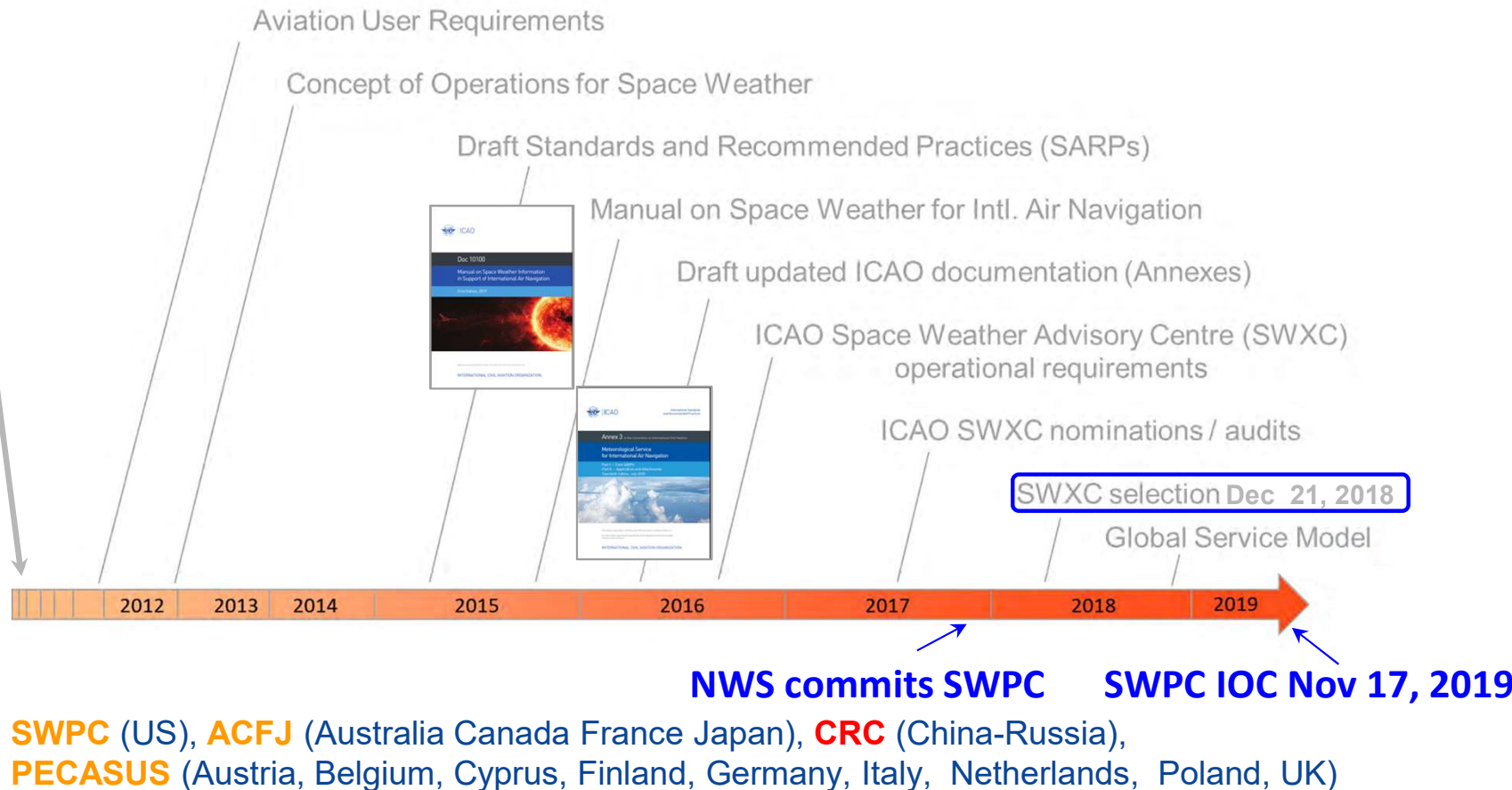


Mission Focus Area: Aviation

ICAO Space Weather Centers (SWXC)

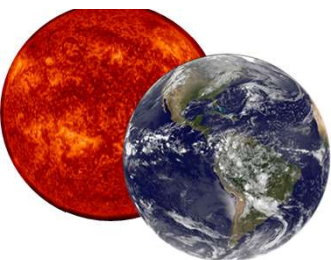


Recommendation: The International Civil Aviation Organization (ICAO), World Meteorological Organization (WMO), International Standards Organization (ISO), and ISES should harmonize their separate standards for aviation space weather information, products, and services based upon a set of requirements.



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Mission Area: Human Spaceflight



New Era of Support - Artemis Lunar Missions and Lunar Surface Operations, Commercial Crew Flights, and future Mars Exploration Missions

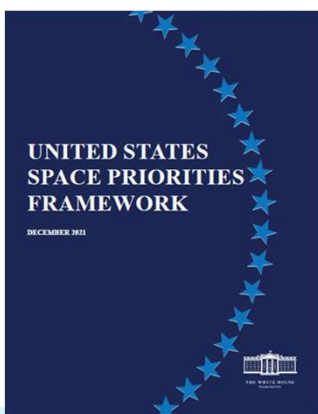
Partnership with SRAG, the Community Coordinated Modeling Center (CCMC), and Moon 2 Mars Office



NONREIMBURSABLE INTERAGENCY AGREEMENT
BETWEEN
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AND UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)
FOR SPACE RADIATION ENVIRONMENT SUPPORT TO NASA

ARTICLE 1. AUTHORITY AND PARTIES

The National Aeronautics and Space Administration, located at 300 E Street SW, Washington, DC 20546 (hereinafter referred to as "NASA") enters into this Interagency Agreement (hereinafter referred to as "IAA") in accordance with 51 U.S.C. § 20113(e). UNITED STATES DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, located at 325 Broadway, Boulder, CO 80305-3337 (hereinafter referred to as "NOAA Space Weather Prediction Center"), enters into this IAA in accordance with Space Act, Other Transactions Authority (OTA), 51 U.S.C. § 20113(e). NASA and NOAA Space Weather Prediction Center may be individually referred to as a "Party" and collectively referred to as the "Parties." NOAA possesses programmatic authority pursuant to 15 U.S.C. § 1532.



United States Space Priorities Framework (Dec 2021)

- The United States will maintain its leadership in space exploration and space science
- The United States will protect space-related critical infrastructure and strengthen the security of the U.S. space industrial base.

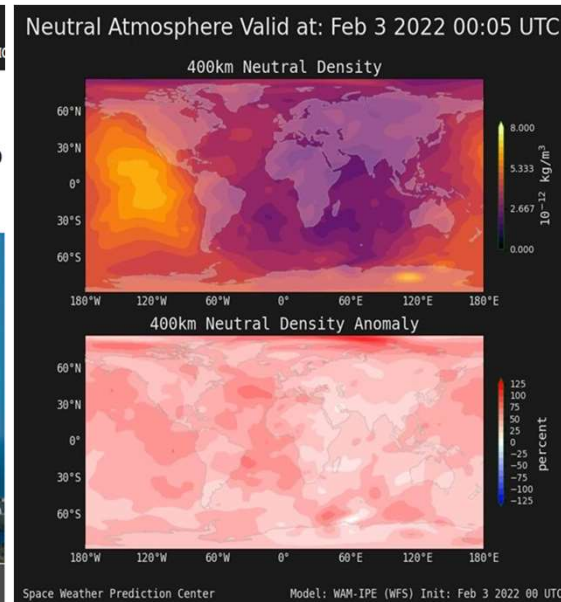


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Mission Focus Area: Space Situational Awareness

- ✦ SpaceX launched **49 Starlink satellites** on Feb 3, 2022
- ✦ **38 lost control and deorbited**
- ✦ Due to **increased drag** during orbit raise from 210 to 380 km
- ✦ Associated with a **minor yet prolonged Geomagnetic Storm** on Feb 3-4

<https://www.weather.gov/news/111522-starlink>



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Mission Focus Area: Power Grid

ESKOM (South Africa)
400 kV EHV Transformer Failures



Transformer #4 HV Winding Damage



Transformer #5 Lead Overheating

Transformer Damage Oct-Nov 2003 Geomagnetic Storm

Oct 2003

Salem GSU Unit #1
(Winding Damage)



Mar 1989

Vulnerability of US grid

- Northern latitude (location of aurora during geomagnetic storms)
- Areas of relatively high resistive igneous rock
- Very high voltage interconnected transmission network
- Proximity to oceans (conductivity of ocean salt water)



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Mission Focus Area: Power Grid

Federal Energy Regulatory Commission (FERC) and North American Electric Reliability Corporation (NERC)

2013: FERC issued Order 779 addressing geomagnetic disturbance (GMD) in two phases:

1. Develop and implement Operating Procedures that can mitigate the effects of GMD
2. Conduct assessments of the potential impact of benchmark GMD events on the grid

2015: NERC Hotline initiated at SWPC. Grid operators across USA and Canada receive all K-7 and higher GMD watches, alerts, and warnings from SWPC.

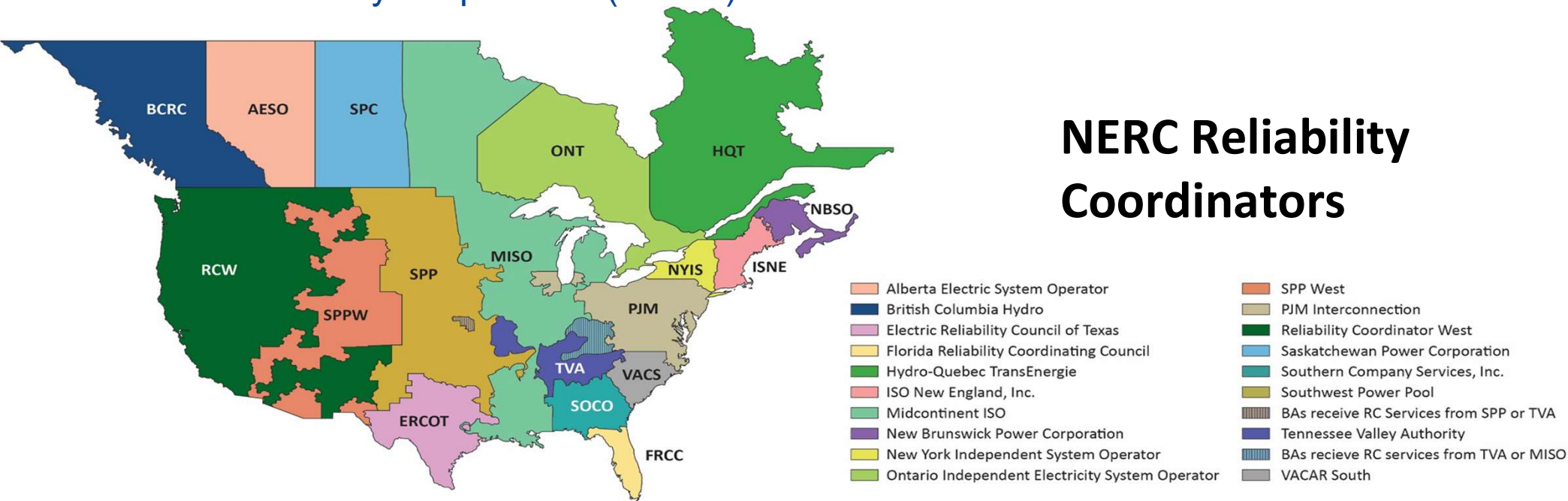
2016: FERC Order No. 830, NERC make collected GIC and magnetometer data available for research and analysis.



Mission Focus Area: Power Grid

Space Weather Event Alert & Notification – Power Grid

SWPC provides warnings to Reliability Coordinators through the North American Electric Reliability Corporation (NERC) Hotline



NERC is the electric reliability organization for North America, subject to oversight by the Federal Energy Regulatory Commission and governmental authorities in Canada



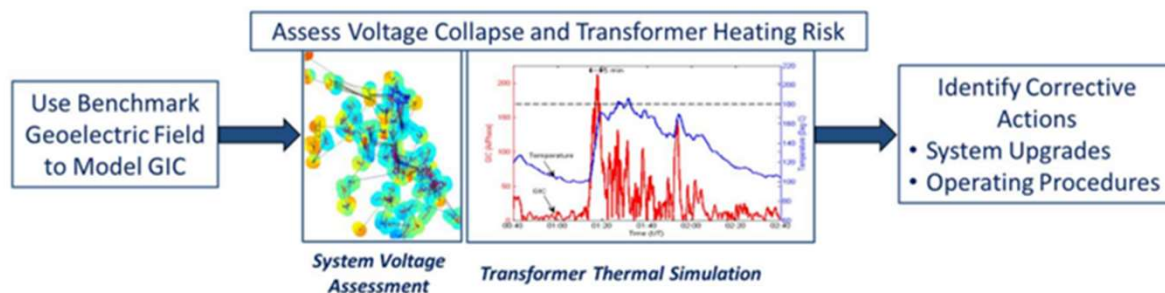
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- Reliability Coordinators and Transmission Operators must have operating procedures to mitigate impacts during GMD events
- Actions include:
 - Relaying space weather warnings
 - System posturing
 - Monitoring for adverse conditions
- Planners and asset owners must to assess and mitigate risks from a 100-year benchmark GMD event



System Operator Electric Reliability
Council of Texas



Mission Focus Area: Research-to-Operations-to-Research Space Weather Prediction Testbed

FY 2023 Budget Provides \$1.75 Million

Space Weather.-Provides \$1,750,000 for Space Weather Research to Operations, including the development of a space weather testbed, as part of NOAA's implementation of the PROSWIFT Act (Public Law 116-181).

- ◆ **New appropriations will permit SPWC to build the Testbed Facility**
- ◆ **Inaugural Testbed Exercise on Aviation Impacts Sept 2022**



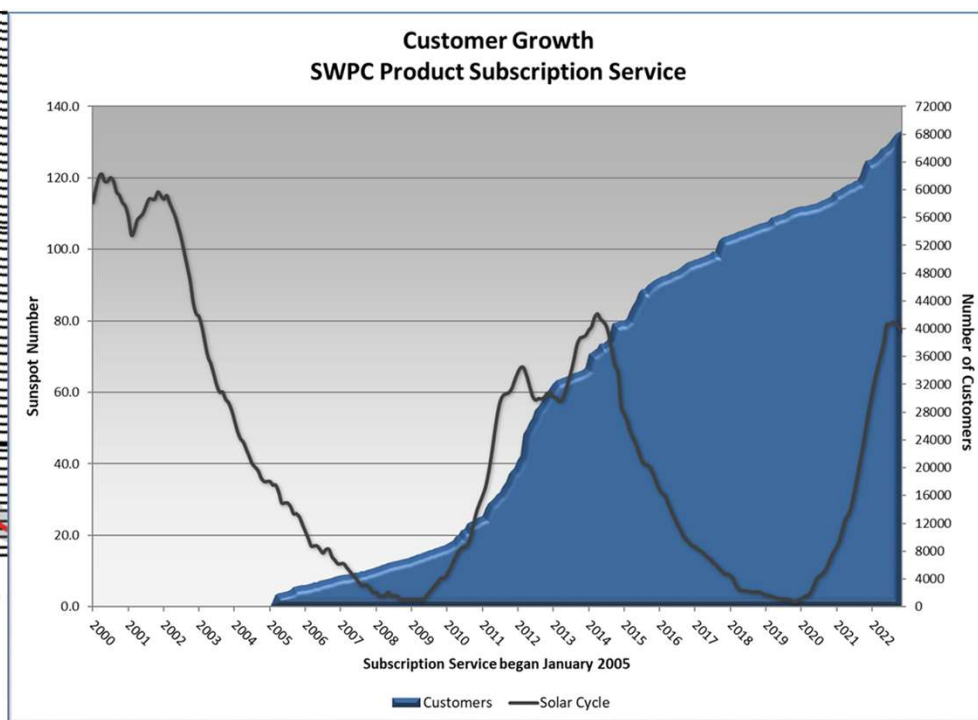
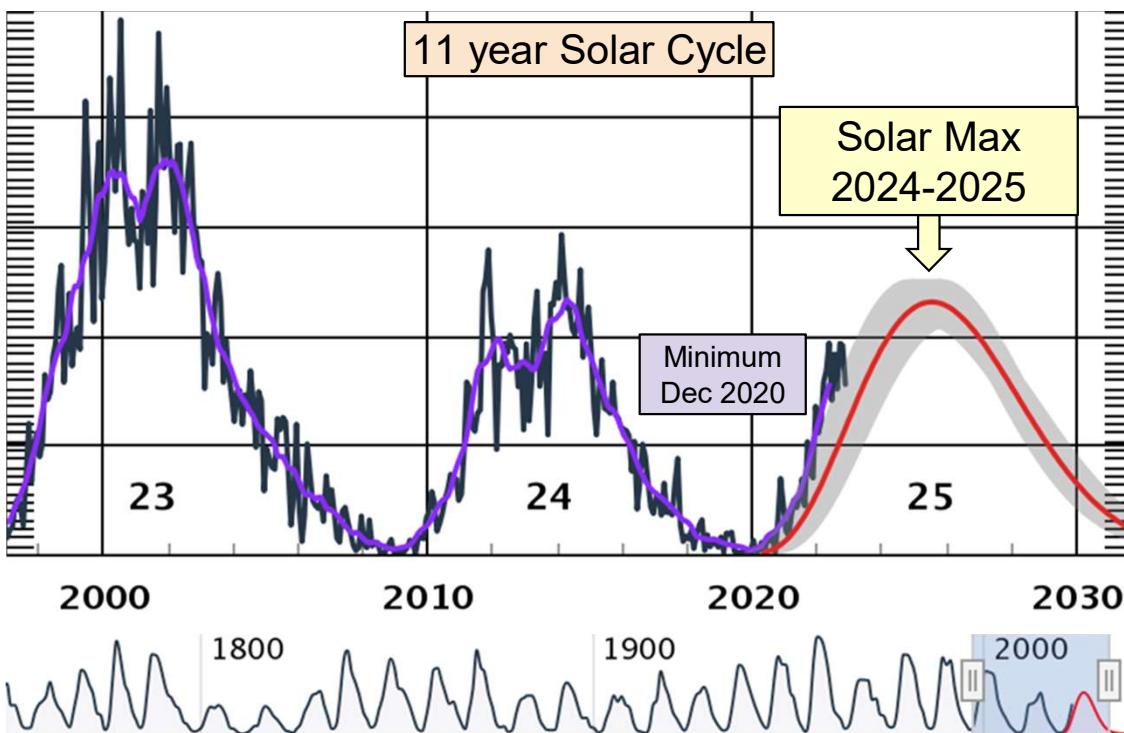
- ◆ **Next Testbed Exercise focused on Space Situational Awareness - April & Sept 2023**



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Approaching Solar Max More Space Weather & Customers

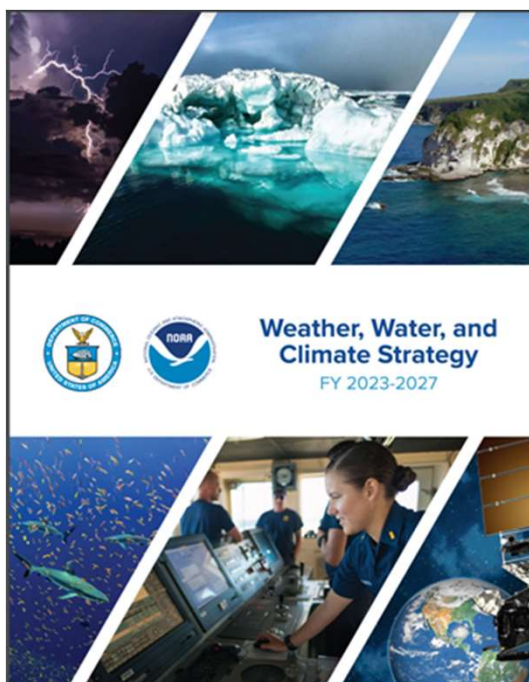


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Space Weather is a Critical Societal Challenge Identified by NOAA



<https://www.noaa.gov/sites/default/files/2022-12/NOAA-FY23-27-Weather-Water-and-Climate-Strategy-12092022.pdf>

Key to enabling decision-making processes for end users is understanding end user needs

- NOAA identified space weather as 1 of 6 critical challenges to address NOAA's mission to protect life and property from extreme events
 - Extreme Events and Cascading Hazards;
 - Coastal Resilience;
 - The Changing Ocean;
 - Water Availability, Quality, and Risk;
 - **Effects of Space Weather**; and
 - Monitoring and Modeling for Climate Change Mitigation



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Department of Commerce // National Oceanic and Atmospheric Administration // 52