



Space Weather Tabletop Exercise (SWx TTX)

8–9 May 2024

Quick Look Briefing

NASEM's Space Weather Round Table

Wednesday, 5 February 2025

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FEMA

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TABLETOP EXERCISE

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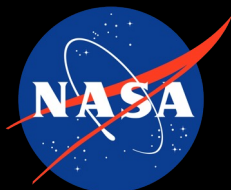


SWx TTX sponsors, partners, and participants at
APL's Collaborative Analysis Center in Laurel, Maryland

Government Participants



SPACE WEATHER
TABLETOP EXERCISE



FEMA



U.S. AIR FORCE

557th
WEATHER
WING



UNITED STATES
SPACE FORCE



COLORADO
Department of Transportation



Executive Summary (1 of 2)



SPACE WEATHER
TABLETOP EXERCISE

Background

- On 8–9 May 2024, APL hosted the first-ever end-to-end Space Weather (SWx) Tabletop Exercise (TTX).
- The hypothetical scenario presented a series of solar events involving a range of impacts on Earth and in cislunar space.
- The TTX was concurrently held at two locations:
 - APL in Laurel, Maryland, for federal participants
 - FEMA Region 8 in Denver, Colorado, for federal, state, local, and tribal participants
- The SWx TTX was designed to provide a low-stress, no-fault environment for generating dialogue about the challenges of preparing for and responding to an impending SWx event.

By chance, the largest geomagnetic disturbance in ~20 years occurred during the TTX. These extraordinary events required key participants to divide their time between the TTX and evolving real-world needs.

Active Space Weather Conditions Through Weekend
WHAT: Large Sunspot Groups and Flares Lead to First G4 Watch Since 2005

- On Thursday, May 9, the NOAA Space Weather Prediction Center issued a Severe (G4) Geomagnetic Storm Watch – the first since January 2005.
- At least five earth-directed coronal mass ejections (CMEs) were observed and expected to arrive as early as midday Friday, May 10, 2024, and persist through Sunday, May 12, 2024. This is an unusual event.
- Several strong flares have been observed over the past few days and were associated with a large and magnetically complex sunspot cluster (NOAA region 3664), which is 16 times the diameter of Earth. Additional solar activity is expected from the region.
- Only three Severe geomagnetic storms have been observed during this solar cycle which began in December 2019. The last G4 (Severe) was on March 23, 2024, and the last G5 (Extreme) was the Halloween Storms in October 2003. That G5 resulted in power outages in Sweden and damaged power transformers in South Africa.

2024-05-09 19:28:00 UTC

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce
Safeguarding Society with Actionable Space Weather Information
Space Weather Prediction Center, Boulder, CO

<https://www.swpc.noaa.gov/news/swpc-issues-its-first-g4-watch-2005>

High-Level Outcomes

1. Demonstrated the need for better **coordination to produce meaningful SWx notifications** that are useful for operations and clearly describe the potential impacts to critical infrastructure
2. Emphasized the importance of a **whole-of-government planning approach** for significant SWx events
3. Provided opportunities to understand **current technology limitations** and discussed possibilities for improved forecasting capabilities
4. Underscored the need for a **national SWx education and awareness** campaign
5. Served as an exemplar event demonstrating the benefits of a **whole-of-government exercise to prepare for scientifically complex threats**
6. Identified the time-critical need for a classified SWx TTX to **identify gaps specific to national security needs** and requirements

Select Opportunities for Improvement (1 of 2)



Planning

- Enhance policies to ensure all government partners with roles and responsibilities involving SWx preparedness have appropriate resources available
- Address the impacts of potential SWx events in Continuity of Operations Plans
- Create a detailed interagency SWx response plan that identifies the final decision maker(s) for resource acquisition, prioritization, and allocation
- Clearly specify roles and responsibilities within the Federal Operating Concept for Impending Space Weather Events

Research and Observations

- Research to better understand the risks to and potential impacts on satellite operations and key vulnerable systems, specifically in the critical infrastructure sectors
- Develop more robust capabilities in forecasting when solar eruptions will occur, as well as the arrival time and geoeffectiveness of coronal mass ejections (CMEs)
- Address the significant observational gaps via new ground- and space-based sources
- Determine opportunities for further international engagement

Select Opportunities for Improvement (2 of 2)



SPACE WEATHER
TABLETOP EXERCISE

Communications and Coordination

- Establish a process to determine when and how to alert senior leaders regarding a SWx event
 - Note: This is currently a component of the Space Weather Operations, Research, and Mitigation (SWORM) Implementation Plan actions and is in progress.
- Establish a broader communication plan, to include a focus on public messaging
- Improve overall understanding of SWx thresholds and when coordination should occur among FEMA, NOAA, NASA, and other agencies for public messaging
- Enhance coordination with critical infrastructure sectors to ensure notification information is meaningful and actionable

Training and Education

- Continue to educate emergency management and public safety agencies across the nation regarding the concept of SWx and its range of potential impacts
- Improve awareness of SWx impacts for critical infrastructure stakeholders and owners
- Provide more training on effective communications for the trusted voices of the community (e.g., fire department, sheriff, local government) to better communicate SWx effects
- Promote the FEMA Emergency Management Institute's "Preparing the Nation for Space Weather Events" (IS-66) course (<https://training.fema.gov/is/courseoverview.aspx?code=IS-66&lang=en>)

Dual Exercise Locations

- Senior leaders at the federal, state, local, and tribal level coordinated across exercise sites in different time zones.
- This dual-location approach allowed for opportunities to explore the many challenges associated with preparing for, protecting against, and mitigating the effects of impending SWx events.



Participants in Laurel, Maryland, from federal departments and agencies



Two locations
interacting virtually,
simulating real-world
coordination



Participants in Denver, Colorado, from Region 8 departments and agencies

Federal, State, Local, and Tribal Coordination Opportunities



The exercise was designed to provide a low-stress, no-fault environment for generating dialogue. The dual-exercise-location format allowed for opportunities to explore the many challenges associated with coordination among federal, state, local, and tribal entities. Below are select outcomes related to opportunities and recommendations for improved coordination between the varying levels of government public safety partners.

Opportunity	Recommendation
SWx is an unfamiliar type of hazard/threat. There are very few planning personnel with experience developing emergency operations plans for an SWx event.	More federal guidance, resources, and scientific expertise are needed to help state and local public safety entities develop SWx emergency operations plans.
There is a clear need to develop public messages and educational information using plain language regarding SWx.	Government departments' and agencies' Emergency Support Function (ESF) 15 (External Affairs and Incident Communication Entities) should work with the NOAA Space Weather Prediction Center (SWPC) and FEMA to develop messaging and coordinate to develop and enhance educational awareness campaigns.
Very few government organizations have followed the recommendation of the 2019 Federal Operating Concept for Impending Space Weather Events, which called on them to evaluate their infrastructure and operational vulnerabilities to space weather events.	Provide further education and awareness to all levels of government to help understand the various impacts an SWx event can have on infrastructure and operations. Provide technical assistance for government departments and agencies on how to conduct vulnerability assessments.

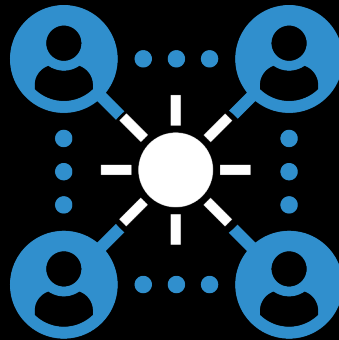
TTX Objectives

Education & Awareness



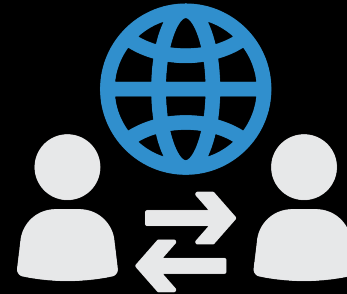
Raise awareness of the nature of SWx and the challenges related to preparing an effective response

Space Weather Preparedness



Enhance whole-of-government preparedness for a multiregional disaster with impact on our nation's critical infrastructure

Information Sharing & Public Messaging



Assess the effectiveness of information and communication protocols and pathways

Cislunar Space Readiness



Assess our resiliency in the face of increasingly degraded space assets due to an SWx event



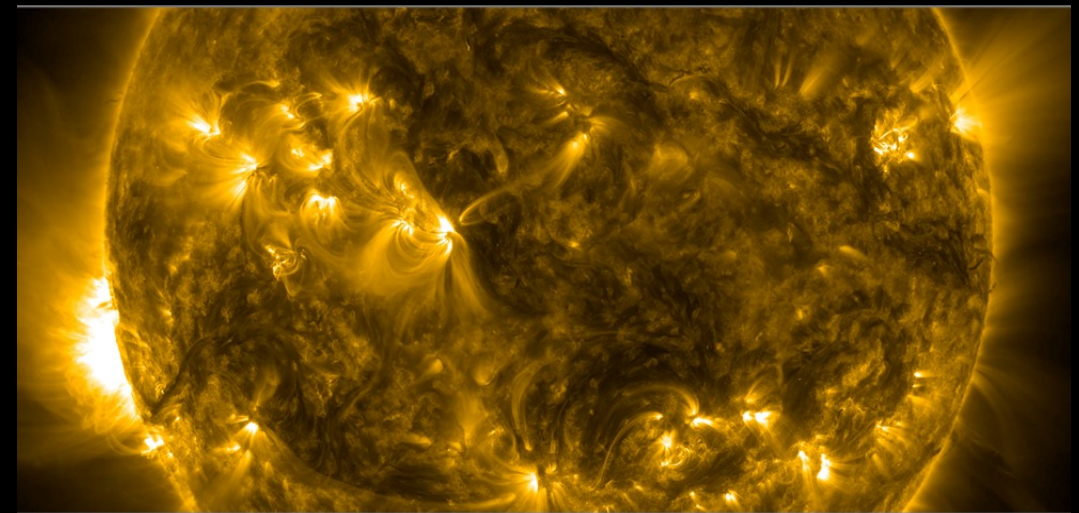
Scenario Overview

The SWx TTX scenario involved a series of solar events culminating in a range of adverse effects on Earth and in cislunar space. Events took place over ~8 days of scenario time from late January to early February 2028.

The scenario began with SWPC tracking an evolving active region on the solar surface with the potential to result in SWx impacts on Earth. The scenario also included an in-progress NASA Artemis IV mission with two astronauts in orbit around the Moon and two astronauts on the Moon's surface preparing for a 7-day lunar exploration mission.

The scenario incorporated solar and geomagnetic activity that resulted in multiple hazards and disruptions, including:

- intense radiation exposure to satellites, astronauts, and commercial aviation,
- communications disruptions and outages,
- loss of functionality or degraded performance of GPS for precision navigation and timing,
- satellite failures and on-orbit collisions, and
- local- to regional-scale power disruptions.





TTX Modules Based on the Scenario

MODULE 0 Introductory Sessions

MODULE 1 Solar Drivers

MODULE 2 Geomagnetic Storm

MODULE 3 Extreme Storm

MODULE 4 Response and Recovery

Space Weather 101

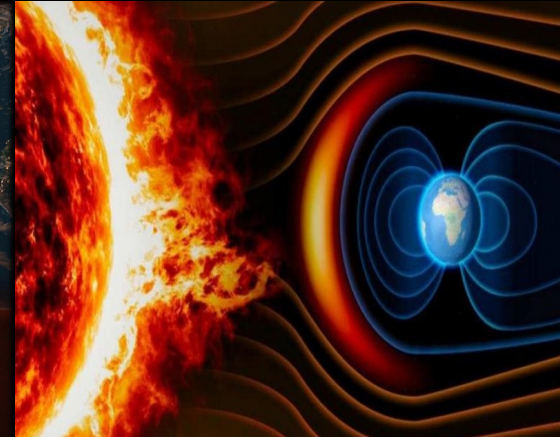
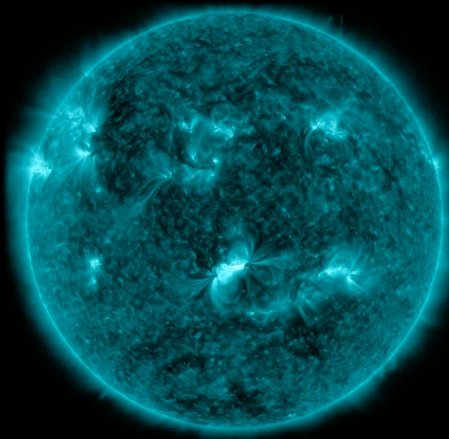
Space Weather
Prediction

Artemis Contingency
Planning

National Response
Framework

National Incident
Management Systems

Federal Operating
Concept



Scenario spanned 26 January 2028 to 03 February 2028

Module 0 Overview and Key Observations



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MODULE 0: Introductory Sessions

Education and awareness briefings were provided regarding the basics of SWx, the NOAA SWPC mission and operations, NASA actions to protect Artemis astronauts, key FEMA guidance documents that dictate roles and responsibilities during disasters, and specific federal guidance to prepare for the impacts of SWx events.

Space Weather 101

Space Weather
Prediction

Artemis Contingency
Planning

National Response
Framework

National Incident
Management Systems

Federal Operating
Concept

Select Observations

- Experts expressed a desire to better understand the impact of SWx events and how they translate to operational functions, as well as how they could impact our nation's critical infrastructure and national security.
- NOAA SWPC gained insight to adjust their customer products to improve usability.
- FEMA encouraged the integration of SWx into preparedness and response planning.
- Interagency team determined that more guidance may be needed to help departments and agencies understand how to conduct vulnerability assessments for an SWx event.
- Participants identified potential information management challenges for both interagency communications and public messaging.
- For SWx events, success may mean the perception that “nothing happened” because notifications were made in a timely manner and appropriate actions were taken.

Module 1 Overview and Key Observations



MODULE 1:

Solar Drivers

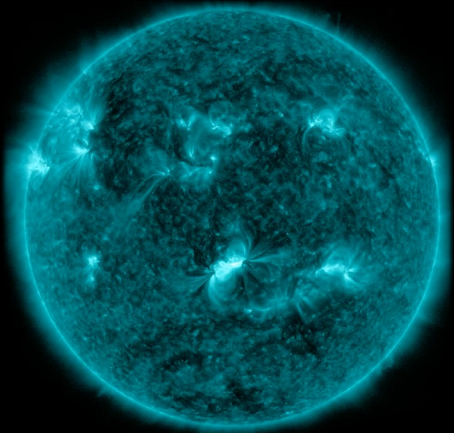
Scenario Timeline:

26 Jan 2028, 3 p.m. ET
(1 p.m. MT) to 28 Jan 2028,
1 p.m. ET (11 a.m. MT)

Module 1 introduced the TTX scenario by noting that SWPC had been tracking an evolving active solar region for the previous 7 days. The active region had rotated into a location where, upon eruption, it would be likely to result in SWx impacts on Earth. NASA's Artemis IV mission was in progress with two astronauts in the Orion command module in orbit around the Moon and two astronauts having just landed in the lunar module on the Moon's surface. TTX participants were provided with a variety of injects, including simulated SWPC notifications, to prompt discussions.

Key Observations

- Noted the lack of predictive capabilities (forecast science) to determine timing and magnitude of SWx events and their effects – *particularly, large solar eruptions*
- Acknowledged need to improve communication channels with a clear decision tree for when information is shared with senior leaders, including establishing interagency calls when an impact likelihood threshold is reached
- Recognized importance of a formal designation of NOAA as the official communication channel and trusted voice for SWx events
- Discussed how to communicate complex SWx information, visual depictions of the potential sequence of events, and the value of including subject-matter experts in the development of public messaging



Module 2 Overview and Key Observations



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MODULE 2:

Geomagnetic Storm

Scenario Timeline:

29 Jan 2028, 2:38 p.m. ET
(12:38 p.m. MT) to 29 Jan 2028,
8:53 p.m. ET (6:53 p.m. MT)

Module 2 opened with a simulated SWx outlook report from FEMA's National Watch Center followed by injects to prompt discussion about radiation effects, degraded communications, and GPS interruptions. Other injects involved potential impacts to critical infrastructure and threats to national security. Module 2 closed with a notification of a second impending CME with very limited warning time.

Key Observations

- Determined that without clear notification thresholds, there is the risk of “notification fatigue” for both government agencies and the general public
- Recognized the need for more clarity when transitioning from a watch to a warning (Specifically, at what level of severity does an SWx notification indicate the need to begin coordinating public information?)
- Affirmed that most government departments/agencies have not completed SWx vulnerability assessments and that more guidance is likely needed
- Reaffirmed the serious limitations (in terms of both the science and the technology) in current SWx forecasting capabilities resulting in a lack of actionable information



Module 3 Overview and Key Observations



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MODULE 3: Extreme Storm

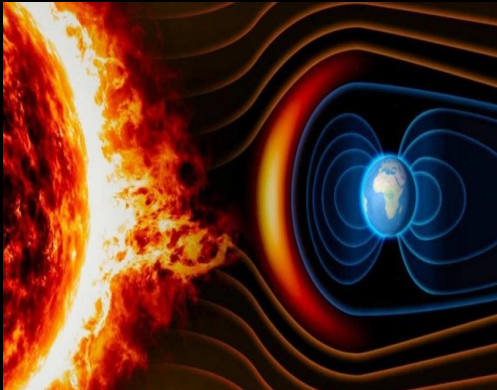
Scenario Timeline:

29 Jan 2028, 9:14 p.m. ET
(7:14 p.m. MT) to 30 Jan 2028,
8 a.m. ET (6 a.m. MT)

Module 3 opened with an update stating that the second CME had hit Earth's magnetosphere and triggered an extreme geomagnetic storm (G5) with solar energetic particle (SEP) intensities peaking during the first ~12 hours. There were numerous impacts on critical infrastructure—explicitly in FEMA Region 8 (R8). Participants were provided with a simulated social media miscommunication inject, prompting a discussion around the need for “trusted voices” and accurate information.

Key Observations

- Recognized the need to provide more guidance to government agencies regarding how to conduct vulnerability assessments specific to impending SWx events
- Discussed information requirements regarding who generates what notifications, and who receives the notifications and through what communication modes
- Recommended developing templates for pre-scripted public messaging content based on thresholds, and determining “trusted voices” for public messaging
- Identified capability gap for predicting N-S direction of interplanetary magnetic field
 - More warning time is needed by emergency responders.
 - There is a need for modeling advances; new imaging technology; solar sail development; full-Sun observing mission concepts; comprehensive ionosphere, thermosphere, and radiation environment monitors; etc.



Module 4 Overview and Key Observations



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MODULE 4: Response and Recovery

Scenario Timeline:

30 Jan 2028, 8:00 a.m. ET
(6:00 a.m. MT) to 03 Feb 2028,
09:20 a.m. (7:20 a.m. MT)

Module 4 focused on key decisions needed 3+ days post-event during the transition from response to recovery. FEMA provided a simulated brief to demonstrate what information FEMA Operations would be tracking, and depicted key information about how the lifelines would be used for planning. R8 participants focused on local issues, including power restoration. Federal participants in Maryland discussed impacts to space assets and touched on national security concerns. Module 4 closed with an inject simulating a NORAD warning of a highly probable satellite collision.

Key Observations

- Revealed the need for clarity regarding how and when Continuity of Operations Plans (COOPs) would be activated for this type of event
- Acknowledged that SWx events can result in vulnerabilities that adversaries can exploit
- Acknowledged that satellite outage reporting is problematic; currently commercial satellite loss-of-control reporting is not routinely done and is not legally required
- Recognized the need for more exercises and training related to SWx forecasting and communications, to include adding a focus on defense support for civil authorities and potential impacts to national security



Select Comments – General Consensus



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“We need to make sure senior leaders understand what’s going on in the space environment so they can have fruitful discussions with interagency partners and contribute to a coordinated response.”

“Kudos. APL did a fantastic job putting this together and executing it – it generated fantastic discussions related to space weather forecasting, messaging, coordination, and response.”

“This has been the best organized and presented TTX I’ve ever attended. Very well done!”

“It did exactly what a TTX is supposed to do. Thank you. Next time, we need more stakeholders involved at all levels of government and the private sector (energy, comms, and space especially).”

“I learned a great deal about FEMA’s and DOE’s roles, activities, and processes in an emergency.”

“Good exercise. Left a lot of to-do items for my agency.”

“Need to get some of joint forces on board, we don’t think they know anything about this yet, or what to do in a space weather event.”

“DoD would benefit from having a classified version of the TTX. Most of our responses have to be vague and obfuscated in an unclassified environment.”

“DOD and IC communities would have responsibilities both within the US and internationally – need discussions here perhaps in follow-on TTX.”

“Limited resources limit the research and capabilities needed to provide better forecasting and understanding of impacts to critical infrastructure.”

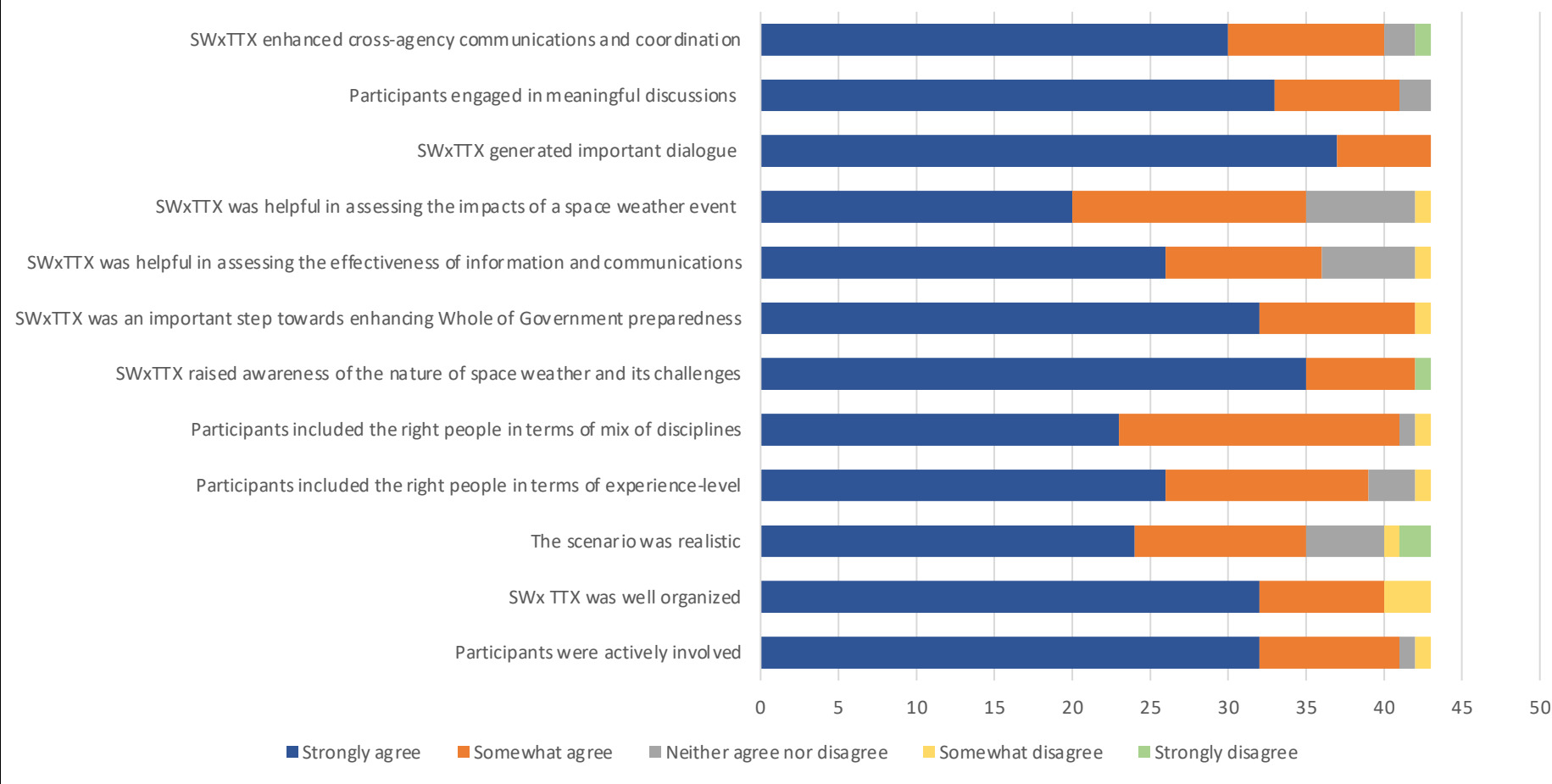
“This event emphasized the need to better understand how critical infrastructure would be impacted, specifically communications systems given there are so many variables involved.”

“The APL TTX team was very well prepared and organized and did a great job. The participation of DoD, FEMA, NOAA, and NASA was strong. Understanding the role and how they do their jobs of the various agencies, in particular FEMA, was eye-opening and very encouraging.”

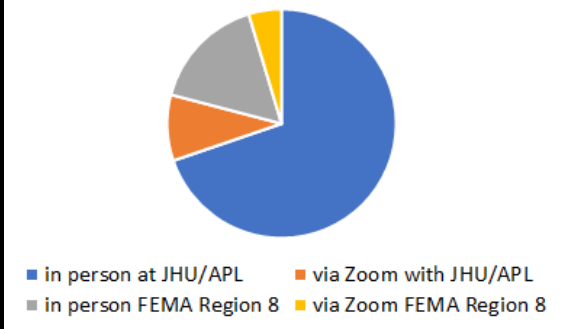
“This exercise was a huge step in the right direction.”

Overall Summary: Participant Feedback Forms

Participants' Feedback for Overall SWx TTX Outcomes



Location of Participant Responses: N = 43



Immediate Impact!



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FEMA National Watch Center

Daily Operations Briefing

Space Weather Summary/Outlook

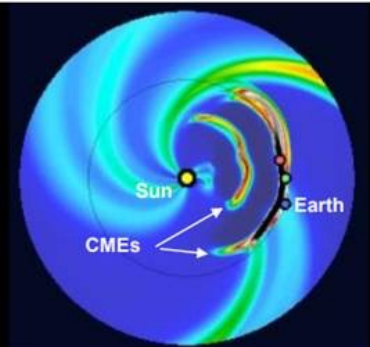
Space Weather Type	Past 48 Hours	Forecast: 10 May	Forecast: 11 May
Solar Flare (Radio Blackout) R Scale (R1-R2/R3)	R3	95% / 60%	95% / 60%
Solar Radiation Storms S Scale	None	50%	50%
Geomagnetic Storms G Scale	None	G1 - 70%	G4 - 70%

KEY MESSAGE: A Severe (G4) Geomagnetic Storm is **LIKELY** – possibly as early as later today and continuing through the weekend. At least five coronal mass ejections are in transit to our atmosphere.

IMPACTS: HF communication, GPS, power grids, and other technologies may be affected. Critical infrastructure operators have been notified.

CONTEXT: Only three Severe (G4) geomagnetic storms have occurred so far this solar cycle, the last being a brief occurrence on March 23rd, 2024.

CAUSE: The source for most of this activity has been a large, complex sunspot cluster (NOAA Region 3664) that is 16 times the diameter of Earth. Additional solar activity from this region is still expected.



- FEMA and SWPC collaboration during the event led to an update of the NWC Daily Brief – the very next day after the TTX!
 - Focus was on *IMPACT* rather than cause

FROM FEMA DAILY OPERATIONS BRIEF (5/13/24)

Identified Impacts: Impacts thus far have been power irregularities, disruptions to navigation systems, and widespread auroras (SWPC)

FEMA/Federal Response: FEMA Response Operations conducted a series of ops coordination calls with SWPC, all 10 FEMA Regions, HQ leadership & program offices. All FEMA regions continue to monitor for impacts; regional watches operating 24/7, all RRCs are rostered.

FEMA Exercise Branch Internal Brief



SPACE WEATHER
TABLETOP EXERCISE



FEMA

SPACE WEATHER TABLETOP EXERCISE 2024

May 8–9, 2024

Laurel, Maryland

Exercise Purpose

The Space Weather Tabletop Exercise 2024 was a two day in-person tabletop exercise hosted at the John Hopkins Applied Physics Lab (APL) in Laurel MD from May 8-9. The exercise aimed to evaluate the effectiveness of communication protocols and response strategies during a simulated space weather event, focusing on improving interagency coordination and national resilience. The exercise was held at two locations with Federal Senior leaders focusing on Federal roles and responsibilities in Laurel, MD and FEMA Region 8 focusing on their specific roles in Denver, CO.

Key Stakeholders

- FEMA HQ & Region 8
- DOT
- NASA
- DOD
- NOAA
- DOE
- White House
- State of Colorado
- NSF
- City of Denver

Exercise Impact

The exercise demonstrated the strengths of Federal communication protocols and fostered enhanced interagency collaboration. It also identified key areas for further dialogue, offering participants a valuable opportunity to explore and learn about the nature of Space Weather events and the Federal response in depth.



FEMA EXERCISE BRANCH
Strengthening capabilities through exercises

100% OF RESPONDENTS THOUGHT THIS
EXERCISE WAS WORTH THEIR TIME

THE EXERCISE ALLOWED FOR 100%
OF PARTICIPANTS TO IDENTIFY BEST PRACTICES AND
AREAS FOR IMPROVEMENT

THE EXERCISE REINFORCED 100%
OF PARTICIPANTS ABILITY TO RESPOND TO FUTURE
SITUATIONS

Recognition

- “The knowledge dropped was spectacular - specifically the knowledge of the threat and impacts that may come. It also highlighted the need for more future engagements and updates to policy and procedures. It had a great mix of professionals in the room who allowed the SMEs to engage when appropriate. This exercise was exceptionally done and well planned and put together. It was evident based on the content, the participation and delivery.”
- “The complex and in-depth scenario, supported by the individual ‘talks’ before we dove in, allowed me to truly understand what was going on and have a firm grasp on the actions needed to move forward”
- Enjoyed the “Tie between presentations from space weather SMEs and opportunities for sidebar conversations.”
- “Engaging with other federal partners”

FEMA Staff at Laurel, MD

- Erik Hooks
- Breanna Means
- Nancy Dragani
- Kelly McKeon
- Rebecca Scarbrough
- Emily Theroux
- Mike Manchester
- Jessica Wieder
- Leviticus “LA.” Lewis
- Gary Merrick (virtual)
- Kenyetta Blunt
- John West
- Vince Dumas
- Rocky Proska
- Joseph “Andy” Couch
- Dennis Red
- Tony Robles
- Kevin Remsberg
- Jared Reese

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2022-2026 FEMA Strategic Plan and/or Annual Planning Guidance Alignment Impact



Goal 1: Instill Equity as a Foundation of Emergency Management

- ☐ Cultivate a FEMA that prioritizes and harnesses a diverse workforce
- ☐ Remove barriers to FEMA programs through a people first approach
- ☐ Achieve equitable outcomes for those we serve



Goal 2: Lead Whole of Community in Climate Resilience

- ☐ Increase climate literacy among the emergency management community
- ☐ Build a climate resilient nation
- ☐ Empower risk-informed decision making



Goal 3: Promote and Sustain a Ready FEMA and Prepared Nation

- ☒ Strengthen the emergency management workforce
- ☒ Posture FEMA to meet current and emergent threats
- ☒ Unify coordination and delivery of federal assistance

Exercise Planning Team

Many organizations helped plan and execute this event



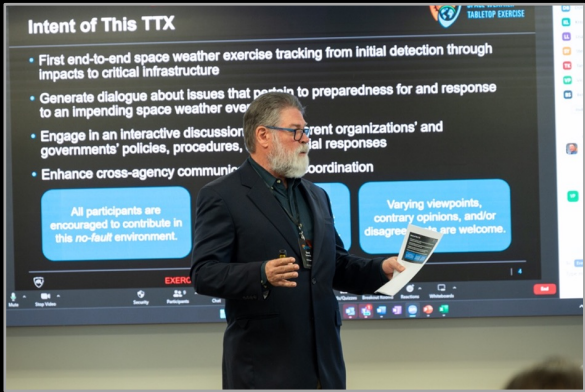
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- **NOAA's Space Weather Prediction Center:** Sponsor; provided direction, SWx expertise, and planning oversight
- **National Science Foundation:** Sponsor; provided direction and expertise
- **NASA:** Sponsor; provided direction and expertise
- **FEMA:** Sponsor; provided guidance and operational expertise and acted as a liaison for state, local, and tribal partners
- **White House Office of Science and Technology Policy (OSTP):** Adviser and planning partner
- **Department of Defense U.S. Air Force:** Adviser and planning partner
- **Johns Hopkins Applied Physics Laboratory (APL):** Lead for planning, execution, evaluation; provided expertise in SWx, critical infrastructure, and emergency management

APL Collaborative Analysis Center, Laurel, MD



FEMA Region 8, Denver, CO





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FEMA