

**WRITTEN STATEMENT BY
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**ON
SPACE WEATHER ACTIVITIES IN THE NATIONAL OCEANIC AND ATMOSPHERIC
ADMINISTRATION**

**COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEES ON SPACE AND ENVIRONMENT
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Introduction

Good morning Mr. Chairman and Members of the Committee. My name is Neil Jacobs and I am the Assistant Secretary of Commerce for Environmental Observation and Prediction at the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce. Thank you for the opportunity to testify at this hearing about space weather. NOAA is the U.S. Government official source of civilian space weather forecasts, warnings, and alerts to the general public, industry, and government agencies. The NOAA Space Weather Prediction Center (SWPC), which is one of nine National Centers for Environmental Prediction within the National Weather Service, has a mission to deliver space weather products and services that meet the evolving needs of the Nation. SWPC operates 24 hours a day, 7 days a week, and provides real-time forecasts and warnings of solar and geophysical events. SWPC works closely with its partner-center in the Department of Defense (DOD), the U.S. Air Force (USAF) 557th Weather Wing. The 557th is responsible for all DOD/National Security needs for space weather information. In addition to the DOD, SWPC efforts are closely integrated with other agencies, including NASA, National Science Foundation (NSF), and the U.S. Geological Survey (USGS), as well as commercial service providers, private industry, and academia. It is SWPC's goal to produce accurate and timely space weather products and decision support tools that protect national critical infrastructure. The importance of SWPC's mission is evident as our Nation relies on technologies and human activities that are vulnerable to space weather impacts.

What is space weather?

Space weather refers to variations in the space environment between the sun and Earth (and throughout the solar system) that can affect technologies in space and on Earth. Space weather is primarily driven by solar storm phenomena that include solar flares, solar particle events, and coronal mass ejections (CME). Solar flares are large eruptions of electromagnetic radiation from the Sun lasting from minutes to hours, and the effects are often referred to as solar flare radio blackouts. Solar energetic particles create radiation storms and occur when an eruption on the Sun accelerates charged particles through interplanetary space. A CME is an expulsion of

billions of tons of plasma gas from the Sun with an embedded magnetic field. CMEs can lead to geomagnetic storms, whose outcome can result in a response partially similar to an electromagnetic pulse (EMP) produced from a high-altitude nuclear detonation. These naturally occurring phenomena have the potential to negatively affect critical infrastructure essential to the Nation's security and economic vitality. Space weather has the potential to disrupt human activities in space and technologies such as the Global Positioning System (GPS), satellite and spacecraft operations, telecommunications, aviation, and the electric power grid—simultaneously affecting large areas, potentially impacting the entire Nation or even wider geographic areas. And it is important to recognize that our critical infrastructure is an interconnected, interdependent system of systems in which the failure of one could cascade to another.

How are forecasts developed and disseminated

A space weather forecast begins with a thorough analysis of the Sun. Forecasters use many different types of solar images from space-based and Earth platforms to analyze active solar regions, localized areas that typically contain enhanced magnetic fields and sunspots. Sunspot groups can be several times the size of Earth and contain complex magnetic structures. Following this analysis, forecasters predict the probability of an eruption on the Sun. When an eruption occurs, forecasters feed the data from the data collection platforms and historical data in our archives into computer models to determine the likely effects of solar events on Earth's ionosphere and magnetosphere. These models help forecasters estimate when the effects will begin, how long they will last, and how severe the event will be.

NOAA is working actively with NASA and NSF to tap into their support of research and space weather modeling developed in the academic community to increase forecast skill. Some of these models have already been tested in a real-time mode at the NASA Goddard Space Flight Center, Community Coordinated Modeling Center. Our focus is to accelerate the transition of research to operations to enable SWPC operational forecasts to be based on these sophisticated models. To date, the NWS now runs two operational models: the George Mason University, Air Force Research Lab, Wang-Sheeley-Arge ENLIL heliosphere model; and the University of Michigan Geospace Model.

SWPC forecasters communicate current and forecasted space weather conditions using a variety of products. Many of the products reference the NOAA Space Weather Scales. Just like there are categories to classify hurricanes, there are also Space Weather Scales for communicating the relative severity of space weather storms. Space weather scales separately map to the aforementioned emissions from the sun - Radio Blackouts (solar flares), Solar Radiation Storms (solar energetic particles), and Geomagnetic Storms (coronal mass ejections). The scales list possible impacts for each level and indicate how often such events happen. Watches, warnings, and alerts are issued by email via a product subscription service and by telephone notification to critical customers such as the various power grid operators and the Federal Emergency Management Agency (FEMA) Operations Center. NOAA's space weather alerts and warnings are key for enhancing national preparedness to space weather. Using these products, the Nation can enhance mitigation, response, and recovery actions to safeguard assets and maintain continuity of operations during space-weather activity.

SWPC ensures all data and services are made available to the growing private sector service providers. The NOAA-private sector partnership plays a vital role in meeting the Nation's needs for space weather services. NOAA makes all of its information available and recognizes that a strong public-private partnership is essential to establish the observing networks, conduct the research, create forecast models and supply the services necessary to support our national security and economic prosperity. NOAA is committed to working toward the growth of the private sector as the national infrastructure demands more space weather services.

Who are the consumers and what actions will they take to mitigate impacts

Space weather presents a variety of hazards to technical systems and human health. SWPC serves a growing and diverse customer base covering a broad spectrum of users. SWPC's Product Subscription Service, which began in 2005 with a few hundred subscribers, ballooned to over 53,000 subscribers just a decade later. All major U.S. airlines subscribe to the service, as do all satellite companies, and all electric power companies.

During severe geomagnetic storms, SWPC forecasters use the 24-hour Emergency Hotline to issue warnings to the 16 Reliability Coordinator centers (RC) across the United States and Canada. The RCs in turn redistribute the information to power companies in their areas of responsibility enabling efforts by those companies to take protective actions.

Likewise, during space weather storms, ground receivers can struggle to lock on to GPS satellites, thus timing and position information becomes less accurate or unavailable. NOAA issues space weather warnings to a variety of public and private industry sectors that rely on GPS, such as oil companies that use GPS services worldwide to position oilrigs and survey vessels. These warnings also go to farmers who rely on GPS for improved crop yield through precise application of pesticides, herbicides, and fertilizers while reducing environmental risks and to construction crews who rely on GPS to improve the productivity, efficiency and safety at their job sites. GPS is also relied upon across the transportation systems sector to improve safety, efficiency and to reduce environmental impacts. As market innovations continue to accelerate the development of autonomous transportation, NOAA will provide the critical information to support safe operations during space weather events in this new transportation paradigm.

Over 15,000 commercial flights flew polar routes in 2017. Airline crews receive a space weather briefing before departing on any polar route. Aviation operators use NOAA space weather information to assess potential impacts— such as communication outages, harmful radiation, and navigation errors—to adjust routes and altitudes.

Spacecraft launch operators use radiation products to avoid electronic problems on navigation systems, preventing launch vehicles from going off course and being destroyed. Space weather effects on satellites can vary from minor interruptions to potential mission failure. Satellite operators rely on space weather products to avoid or analyze problems on their spacecraft. NOAA's forecasts and observations are also important input to manned spaceflight operations. Activities onboard the International Space Station are altered to avoid or mitigate effects of radiation storms impacting crew safety and technological systems. Accurate space weather

information will be important when we return Americans to the surface of the Moon and onward to Mars.

Space weather forecasts are also important inputs to support DOD communications, USAF flight operations, U.S. Navy strike forces, and U.S. Army Special Forces. NOAA's Geostationary Operational Environmental Satellites (GOES) provide the basis for classified and unclassified data for the DOD. In fact, 80% of the DOD space weather alerts and warnings rely on GOES data. The National Defense Authorization Act for Fiscal Year 2018 calls for an assessment of the nature, magnitude, and likelihood of potential EMP, both manmade and natural, that could be directed at or affect the United States within the next 20 years.

A growing number of SWPC customers are realizing social and economic benefits from space weather products and services. NOAA is addressing the accelerating growth in our space weather customer base by improving our understanding of customer needs and by defining new services in response to the evolving needs and requirements of a global high-tech economy.

Observation Platforms

NOAA utilizes an array of space-based and ground based observations in our space weather forecast operations and related research. Many of these data sets are available in near real-time, and come from a variety of sources, ranging from solar imaging satellites to ground magnetometer stations. In addition to NOAA operational assets, we have partnerships with other organizations such as NASA, NSF, USAF, and USGS to utilize data from these agencies to complement the NOAA observations.

Currently, NOAA relies on the European Space Agency/NASA's Solar Heliospheric Observatory (SOHO) for CME imagery. The life expectancy of SOHO, which was launched in 1995, is limited by the power produced from its solar arrays. Solar arrays degrade over time and the latest engineering analysis indicates that by 2025, there will be insufficient power for the satellite to operate. At this time, there is no back up for CME imagery. With the eventual power loss, NOAA will lose access to CME imagery. Without CME imagery, the 1- to 4-day lead-time of likely storm conditions will be degraded, thereby affecting the accuracy of geomagnetic storm watches. NOAA started developing a flight compact coronagraph (CCOR) to obtain CME imagery in 2017, and will continue to work with the U.S. Naval Research Laboratory (NRL) to obtain the quickest possible delivery of the CCOR instrument. NOAA is currently evaluating an option to host the CCOR on the GOES-U satellite on its Sun-Pointing Platform (SPP).

NOAA also relies on NSF's Global Oscillations Network Group (GONG), which provides ground-based observations of the solar magnetic field. GONG consists of a network of six stations that provide imaging and magnetograms on a 24/7 basis. GONG is currently undergoing a modernization program to make it operationally ready to provide critical data inputs to SWPC space weather models. NOAA provides partial support for GONG operations through a 5-year interagency agreement with NSF.

Real-time measurements of the highly variable solar winds are vital for assessing space weather conditions in near-Earth space within the atmosphere and on the ground. For solar wind data upstream of Earth, NOAA uses its Deep Space Climate Observatory (DSCOVR) stationed at

Earth-Sun Lagrange point 1 (L1). DSCOVR is a research-grade satellite and is susceptible to mission failure with the loss of any of several single string critical components. For backup, we use the NASA Advanced Composition Explorer (ACE) spacecraft. ACE (launched in 1997) is limited by fuel used for orbit station-keeping and will run out of fuel in 2026. Loss of in-situ monitoring of solar winds without a replacement will cripple NOAA's ability to provide short-term warnings (15-45 minutes) of space weather storms. NOAA is exploring a partnership with NASA to fly a NOAA Space Weather Follow-On (SWFO) spacecraft as a rideshare with the NASA 2024 Interstellar Mapping and Acceleration Probe (IMAP) launch to L1. As a part of this effort, NOAA will conduct assessments on potential instruments for a solar wind mission.

Additionally, NOAA is exploring commercial opportunities for solutions to meet U.S. government requirements for space weather observations. These commercial solutions could include: the availability of space and resources for U.S. government sensors or instruments on commercially manifested satellite missions (i.e., hosted payloads); commercial satellite systems that complement or meet U.S. government observing requirements; and purchasing commercial space weather observations (i.e. data buys).

To obtain continuous data from DSCOVR and ACE, NOAA relies on a network of ground tracking stations located at various sites around the world. Our foreign partners include the National Institute of Information and Communications Technology in Tokyo, Japan; the Korean Radio Research Agency Space Weather Center in Jeju, Korea; and the German Aerospace Center in Neustrelitz, Germany.

The underpinning data used by NOAA to supply the Nation with geomagnetic storm warnings and alerts are the ground-based magnetic field observations provided by the USGS Geomagnetism Program. NOAA's geomagnetic storm alerts and warnings are based on the USGS magnetometers. These observations describe the local intensity of the changes in magnetic fields and allow NOAA to characterize the intensity of the geomagnetic storm.

NOAAs Interagency Coordination with SWORM

In November 2014, the Space Weather Operations, Research, and Mitigation (SWORM) Task Force was established by action of the National Science and Technology Council (NSTC). It was tasked with uniting the national- and homeland-security enterprise with the science and technology enterprise to formulate a cohesive approach to enhance national preparedness for space weather. As a result, the National Space Weather Strategy and associated Action Plan¹ were published in October 2015. Executive Order (EO) 13744 – Coordinating Efforts to Prepare the Nation for Space Weather Events, was signed in October 2016.

These documents together identify 105 actions for Executive departments and agencies to prepare the Nation for space weather storms. To maximize efficiency in our efforts to complete the goals in the National Space Weather Strategy, NOAA is committed to strong public-private partnerships between the Federal Government, industry, and academia. And given the global threat of space weather, and because the United States has key assets across the world, we must

¹https://www.sworm.gov/publications/2015/swap_final__20151028.pdf

also work with international partners to build adaptive capacity and increase resilience to space weather.

On April 19, the Office of Science and Technology Policy announced the development of an update to the National Space Weather Strategy. This important initiative seeks to improve government coordination on long-term guidance for Federal programs and activities to enhance national preparedness to space weather events. The revised strategy will align with priorities identified by the Administration in the 2017 National Security Strategy (NSS), and the Space Policy Directive – 1. The NSS promotes American resilience through improving our ability to withstand and recover rapidly from natural disasters and other threats to our economy and democratic system. It recognizes that in the event of a disaster, Federal, state, and local agencies must perform essential functions and have plans in place to ensure the continuation of government. Space Policy Directive – 1 provides for a U.S.-led, integrated program with private sector partners for a human return to the Moon, followed by missions to Mars and beyond. Outside Earth’s protective magnetic field and atmosphere, the radiation in space will pose a serious risk to astronauts as they travel to the Moon, Mars and beyond. Space weather forecasts will be important for the safety of our astronauts on deep space missions.

On April 20, NOAA released a Request For Information (RFI) seeking input from the public on ways to improve government coordination and on long-term guidance for Federal programs and activities to enhance national preparedness to space weather events. The RFI also includes the opportunity for the private sector to provide information regarding commercial activities associated with space weather prediction, observation, or the transitioning of research to operations. Specifically, NOAA will utilize the input to enable and advance the private sector role for capabilities, forecasting, modeling, mitigation, research, development, and observation in the space weather domain.

NOAA will continue to work and partner with other Federal agencies in this renewed effort to develop and strengthen our activities in space weather research and forecasting. And we recognize the importance of engaging public and private expertise in a whole community approach, engaging public and private expertise to enhance the resiliency and security of our Nation to space weather storms.