



**SUBCOMMITTEE ON ENVIRONMENT
HEARING CHARTER**

“From Orbit to Operations: How Weather Satellites Support the National Security Mission”

**Tuesday, January 13, 2026
10:00 a.m.
2318 Rayburn House Office Building**

Purpose

The purpose of this hearing is to examine the role of the nation’s weather satellite architecture in supporting the national security mission. The Committee will review how the National Oceanic and Atmospheric Administration (NOAA) collaborates with the United States Air Force and the United States Navy to meet the full range of weather data requirements necessary for strategic and operational readiness and safety. The hearing will also consider how interagency partnerships can enhance communication to ensure the use of the highest-level data security measures while safeguarding access to critical information needed for timely and accurate weather forecasting. Finally, the hearing will provide an opportunity for Members to discuss potential areas of improvement and their priorities related to the collection, distribution, and use of weather data.

Witnesses

- **Mrs. Irene Parker**, Deputy Assistant Administrator for Systems, National Environmental Satellite, Data, and Services (NESDIS), National Oceanic and Atmospheric Administration
- **Colonel Bryan Mundhenk**, Chief, Weather Operations Division, United States Air Force
- **Dr. Christopher Ekstrom**, Deputy Chief of Naval Operations for Information Warfare (N2N6); Deputy Director, Oceanography & Navigation, United States Navy

Background

This hearing will include testimony from individuals in the meteorological and defense communities who work to enhance the sustainability and accuracy of federally provided weather information to inform the Committee as it looks towards authorizing the next generation of weather satellites. This conversation will include insight on what data is currently available; how NOAA

and its military partners supplement gaps in data, and which of these gaps need to be filled in the short and long-term.

NOAA

NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), provides secure and timely access to global environmental data and information from satellites and other sources to promote and protect the nation's security, environment, economy, and quality of life.¹ It is the satellite arm of the agency and operates 24 hours a day 365 days a year in both Low Earth orbit (LEO) and Geostationary Orbit (GEO). Critical images and data generated and housed at NESDIS are used by billions worldwide.



Source: NOAA NESDIS²

This information starts with raw data from their constellation of weather and environment-monitoring satellites and ends up with products and services used daily across the country. The data NESDIS provides is used by the National Weather Service, scientists across NOAA, the federal government, the commercial sector, and private citizens for a wide range of applications. Ninety-five percent of the data used in weather forecasting models comes from satellites.³ They also maintain international data-sharing agreements that provide the U.S. with access to global data.⁴

¹ *Our mission*. National Environmental Satellite, Data, and Information Service.

<https://www.nesdis.noaa.gov/about/our-mission>

² *Infographics*, National Environmental Satellite, Data, and Information Service. [NOAA-Satellite-Observing-System-June-2025-Low-Res.png.webp \(1920×1080\)](#).

³ *What we do*. National Environmental Satellite, Data, and Information Service.

<https://www.nesdis.noaa.gov/about/what-we-do>

⁴ *Id.*

The current NOAA satellite architecture is made up of GEO and Polar LEO constellations as well as deep space satellites located at Lagrange Point 1 (L1). L1 is the neutral gravity point between the Earth and Sun where the gravitational force of the Sun equals the gravitational force of Earth enabling satellites to maintain a static position. L1 is approximately one million miles from Earth.⁵

The FY24 enacted budget for NOAA NESDIS is \$1.80 billion dollars. The total Operations, Research and Facilities (ORF) budget is \$386.9 million, and the Procurement, Acquisition, and Construction budget is \$1.414 billion.⁶ These numbers have held steady since the government is operating on a Continuing Resolution. H.R. 6938 passed the House on January 8, 2026, with \$6.11 billion appropriated to NOAA but has not yet been enacted into law.⁷

Geostationary Satellites

NOAA's Geostationary Operational Environmental Satellites (GOES) are a sophisticated weather-observing and environmental-monitoring system that provide advanced imagery and atmospheric measurements, real-time mapping of lightning activity, and monitoring of space weather.⁸ The location of the GOES satellites is 22,236 miles above Earth's equator, and moves at speeds equal to the Earth's rotation⁹ allowing the satellites to maintain their positions over specific geographic regions so they can provide continuous coverage of that area over time.

NOAA operates the GOES-R Series to provide critical atmospheric, hydrologic, oceanic, climatic, solar and space data, and to significantly improve detection and observation of environmental phenomena that directly affect public safety, protection of property, and our nation's economic health and prosperity. This includes:

- Improved hurricane track and intensity forecasts
- Increased thunderstorm and tornado warning lead time
- Earlier warning of lightning ground strike hazards
- Better detection of heavy rainfall and flash flood risks
- Better monitoring of smoke and dust
- Improved air quality warnings and alerts
- Better fire detection and intensity estimation
- Improved detection of low clouds and fog
- Improved transportation safety and aviation route planning
- Improved warning for communications and navigation disruptions and power blackouts
- More accurate monitoring of energetic particles responsible for radiation hazards¹⁰

The GOES-R series of satellites were designed as a uniform collection of four satellites, each carrying the same six instruments (GOES-U has an additional instrument for a total of seven) to

⁵ *Points of Lagrange: A Satellite a Million Miles from Home*, National Environmental Satellite, Data, and Information Service. (Oct. 26, 2015), <https://www.nesdis.noaa.gov/news/points-of-lagrange-satellite-million-miles-home>.

⁶ <https://www.noaa.gov/sites/default/files/2025-06/NOAA%20FY26%20Congressional%20Justification.pdf>.

⁷ H.R.6938 - 119th Congress (2025-2026): Commerce, Justice, Science; Energy and Water Development; and Interior and Environment Appropriations Act, 2026, H.R.6938, 119th Cong. (2026), <https://www.congress.gov/bill/119th-congress/house-bill/6938>.

⁸ *Geostationary Satellites*, National Environmental Satellite, Data, and Information Service. (Nov. 20, 2025), <https://www.nesdis.noaa.gov/our-satellites/currently-flying/geostationary-satellites>.

⁹ *Id.*

¹⁰ *Id.*

provide consistent atmospheric measurements over the lifespan of the mission, from 2016 to 2036.¹¹ See Appendix A for list instruments. Each satellite is designated with a letter during development and renamed with a number after reaching geostationary orbit.

GOES-U (now GOES-19) was launched in 2024 and operates as NOAA's GOES East satellite, while GOES-T (now GOES-18), was launched in 2022 and is NOAA's operational GOES West satellite. GOES-R (now GOES-16), launched in 2016, and GOES-S (now GOES-17) launched in 2018, both serve as on-orbit backups.¹²

The GOES-R mission design is for a two-satellite operational system to provide persistent observational coverage for the entire U.S. The importance of the data collected by the GOES satellites for weather forecasting requires NOAA to maintain an on-orbit spare GOES satellites parked between the East and West satellites. The spare provides immediate backup in the event of an anomaly or failure of either of the operational satellites in orbit.¹³

The GOES-R Program is a collaborative effort between NOAA and the National Aeronautics and Space Administration (NASA). NASA builds and launches satellites for NOAA, which operates them and distributes their data to users worldwide.¹⁴

Next Generation Geostationary

NOAA's Geostationary Extended Observations (GeoXO) satellite system will expand observations of Earth that the GOES-R Series currently provides from geostationary orbit. The information GeoXO supplies will improve short-term forecasting and warn of severe weather and hazards that threaten the security and well-being of everyone in the Western Hemisphere.¹⁵

The first GeoXO launch is planned for 2032 to ensure continuity of observations from geostationary orbit as the GOES-R Series nears the end of its operational lifetime. New technology and scientific advancements will improve observations of short-term weather forecasts and severe storm warnings. GeoXO will also detect and monitor environmental hazards like wildfires, smoke, dust, volcanic ash, drought, and flooding, providing advance warning to decision makers and improving lead times for public alerts.¹⁶

Low Earth Orbit (LEO) Satellites

NOAA's Joint Polar Satellite System (JPSS) provides global observations that serve as the backbone of both short- and long-term forecasts, including those that help us predict and prepare

¹¹ GOES-R Series, *Mission & Mission Overview*, NOAA/NESDIS/STAR (last visited Jan. 8, 2026), <https://www.goes-r.gov/mission/mission.html>.

¹² *Geostationary Satellites*, National Environmental Satellite, Data, and Information Service. (Nov. 20, 2025), <https://www.nesdis.noaa.gov/our-satellites/currently-flying/geostationary-satellites>.

¹³ GOES-R Series, *Mission & Mission Overview*, NOAA/NESDIS/STAR (last visited Jan. 8, 2026), <https://www.goes-r.gov/mission/mission.html>.

¹⁴ *Geostationary satellites*. National Environmental Satellite, Data, and Information Service. <https://www.nesdis.noaa.gov/our-satellites/currently-flying/geostationary-satellites>

¹⁵ *Geostationary extended observations (geoxo)*. National Environmental Satellite, Data, and Information Service. <https://www.nesdis.noaa.gov/our-satellites/future-programs/geostationary-extended-observations-geoxo>

¹⁶ *Id.*

for severe weather events. JPSS is vital to create three- to seven-day mid-range forecasts, provide support for operational forecasting in polar regions, and are invaluable for observing rapid intensification of hurricanes.¹⁷

The five satellites scheduled in the constellation are the currently flying NOAA/NASA Suomi National Polar-orbiting Partnership (Suomi NPP) satellite, NOAA-20 (previously known as JPSS-1), NOAA-21 (previously known as JPSS-2), and the upcoming JPSS-3 and JPSS-4 satellites.¹⁸ See Appendix B for list of instruments.

JPSS satellites orbit Earth from pole to pole 14 times a day, ensuring full global coverage twice daily. In doing so, they provide most of the data that informs numerical weather forecasting in the U.S. and deliver critical observations during severe weather events.¹⁹

Orbiting at 17,500 miles per hour, NOAA's Constellation Observing System for Meteorology, Ionosphere, and Climate-2 (COSMIC-2) is made up of six remote-sensing small satellites that form a network and use a technique called radio occultation to collect information on our planet's atmosphere. NOAA is partnering with the U.S. Air Force (USAF), U.S. Space Force (USSF), Taiwan's National Space Organization (NSPO), and the University Corporation for Atmospheric Research (UCAR) on this environmental satellite program.²⁰

Jason-3 is a satellite mission that supports scientific, commercial and practical applications related to sea level rise, ocean circulation, and climate change. Jason-3 follows the current operational altimeter satellite, Jason-2, in maintaining satellite altimetry observations of global sea surface height. Jason-3 is an international cooperative mission in which NOAA is partnering with the Centre National d'Etudes Spatiales (CNES, France's governmental space agency), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), and National Aeronautics and Space Administration (NASA).²¹

National Polar-orbiting Operational Environmental Satellite System (NPOESS)

Given the similar needs of NOAA and the Department of Defense (DoD) for data polar-orbiting weather satellites, President Bill Clinton issued a directive on May 5, 1994, to merge the military and civil meteorological programs into a single environmental weather satellite program. This directive created the NPOESS program. Three government agencies were given responsibilities for this new program: NOAA for satellite operations, DoD for acquisitions, and NASA for development and infusion of new technologies.²² In 2000, the NPOESS program anticipated purchasing six satellites for \$6.5 billion with the first to launch in 2008. In 2002, the NPOESS

¹⁷ Weinrich, *NOAA's Next-Generation Polar Orbiting Environmental Satellite System*, (June 18, 2019), https://www.weather.gov/media/psr/Weinrich_JPSS.pdf.

¹⁸ *Joint Polar Satellite System*, National Environmental Satellite, Data, and Information Service. (Dec. 22, 2025), <https://www.nesdis.noaa.gov/our-satellites/currently-flying/joint-polar-satellite-system>.

¹⁹ *Id.*

²⁰ *Cosmic-2*. National Environmental Satellite, Data, and Information Service. <https://www.nesdis.noaa.gov/current-satellite-missions/currently-flying/cosmic-2>

²¹ *Jason-3*. National Environmental Satellite, Data, and Information Service. <https://www.nesdis.noaa.gov/current-satellite-missions/currently-flying/jason-3>

²² National Research Council. 2008. *Options to Ensure the Climate Record from the NPOESS and GOES-R Spacecraft: A Workshop Report*. Washington, DC: The National Academies Press.

Preparatory Project (NPP) was created to demonstrate and validate new instruments and processes.²³ However, by November 2005, the cost overruns for the program exceeded 25%, triggering an automatic review process by DoD.²⁴ As a result of the review, NPOESS was reduced from six satellites to four, initial launch was postponed until 2013, and some instruments were dropped or descoped.

Despite the attempt to consolidate these weather satellite requirements into a single program, it became clear that NPOESS was not providing the cost savings or efficiencies originally envisioned. In 2010, President Barack Obama decided to dissolve the program into three parts: the Joint Polar Satellite System (JPSS) – which would continue to be a joint venture with NOAA and NASA; the Defense Weather Satellite System (DWSS) – which would be the DoD’s program to follow DMSP; and partnership with the European Organisation for the Exploitation on Meteorological Satellites (EUMETSAT) Metop satellites – which would provide one of the three orbits originally planned under NPOESS. In October 2011, the NPP satellite (originally designed as a research and demonstration satellite) became the first operational LEO satellite in the new program.²⁵

Lagrange 1 (L1) Satellites

The Deep Space Climate Observatory, or DSCOVR, was launched in February 2015, and maintains the nation's real-time solar wind monitoring capabilities, which are critical to the accuracy and lead time of NOAA's space weather alerts and forecasts. Timely and accurate warnings of space weather events, such as geomagnetic storms, are necessary to help protect major public infrastructure systems, including power grids, telecommunications, aviation and global positioning systems (GPS).²⁶

From its position at L1, DSCOVR can typically provide 15- to 60-minute advanced warning before a storm of particles and magnetic field, known as a coronal mass ejection (or CME), reaches Earth. DSCOVR data also helps improve predictions of geomagnetic storm impact locations. U.S. national security and economic well-being, which depend on advanced technologies, are at risk without these advanced warnings.²⁷

Space Weather Follow On-Lagrange 1 (SWFO-L1) observes the Sun and near-Earth environment for space weather activity, using a special solar telescope to monitor the Sun's activity in addition to a suite of instruments to make real-time measurements of the solar wind.²⁸ It is the first of a next generation of observatories to replace space weather monitoring for operations at L1 for legacy

²³ *SNPP Operational Status*, National Environmental Satellite, Data, and Information Service <https://www.nesdis.noaa.gov/our-satellites/currently-flying/snpp-operational-status>.

²⁴ National Research Council. 2008. *Options to Ensure the Climate Record from the NPOESS and GOES-R Spacecraft: A Workshop Report*. Washington, DC: The National Academies Press.

²⁵ *SNPP Operational Status*, National Environmental Satellite, Data, and Information Service. <https://www.nesdis.noaa.gov/our-satellites/currently-flying/snpp-operational-status>.

²⁶ *DSCOVR: Deep Space Climate Observatory*, National Environmental Satellite, Data, and Information Service (Jan. 9, 2026), <https://www.nesdis.noaa.gov/current-satellite-missions/currently-flying/dscovr-deep-space-climate-observatory>.

²⁷ *Id.*

²⁸ *Space Weather Follow On-Lagrange 1 (SWFO-L1)*, National Environmental Satellite, Data, and Information Service. <https://www.nesdis.noaa.gov/our-satellites/future-programs/swfo/space-weather-follow-lagrange-1-swfo-l1>.

satellites that have been operating for more than 30 years.²⁹

The 24/7 data from SWFO-L1 will be constantly streamed to Earth in real time without interruption or obstruction. CME imagery will be available to space weather forecasters within 30 minutes of acquisition. This is a significant improvement over the current eight-hour notice, which gives operators critical lead time to take precautionary actions to protect vital infrastructure, economic interests, and national security both on Earth and in space.

SWFO L-1 launched from Kennedy Space Center on September 24, 2025, and is expected to enter operations in mid-2026.³⁰

United States Air Force

Air Force weather operations provide global predictions of impacts from environmental effects. Meteorologists within the Department of the Air Force (DAF) deliver environmental information, products, and services to gain and maintain a warfighting advantage. They also provide information on weather effects relevant to operations at the strategic, operational, and tactical levels of warfare.³¹ The DAF recognizes weather as a critical operational factor and has established robust procedures to provide commanders with the environmental information they need to make informed decisions. Commanders leverage this advantage to integrate, synchronize, and direct operations, and outmaneuver the adversary more effectively. USAF weather operations directly support the DAF and United States Army (Army) conventional and special operations forces (SOF).³²

The two key functions of DAF weather operations are characterization and exploitation, in alignment with the joint Meteorological and Oceanographic (METOC) functions. Weather forces characterize the environment through the collection, analysis, and prediction of weather data from both military and civilian sources such as NOAA weather data, along with constant dissemination for operational advantage.³³

Within DAF is the 557th Weather Wing. Headquartered at Offutt Air Force Base, Nebraska, the 557th is comprised of 1,450 personnel in two groups and 12 squadrons spanning 17 globally dispersed locations. Through the 1st and 2d Weather Groups, the 557th wing can capitalize on global terrestrial and space-environmental intelligence to better meet the dynamic needs of Air Force, Army, and specialized military activities in contested, degraded, or operationally limited environments.³⁴

Artificial Intelligence and Machine Learning for Weather

Within the 557th Weather Wing, the 16th Weather Squadron prototypes and operates Artificial

²⁹ *Id.*

³⁰ *SWFO-L1 launch*. National Environmental Satellite, Data, and Information Service. <https://www.nesdis.noaa.gov/news-events/swfo-l1-launch>

³¹ Air Force Doctrine Publication 3-59, Weather Operations 26 September 2025. https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-59/3-59-AFDP-WEATHER-OPS.pdf

³² *Id.*

³³ *Id.*

³⁴ *Quick links*. About Us. <https://www.557weatherwing.af.mil/About-Us/>

Intelligence (AI) and Machine Learning (ML) and big data software applications.³⁵ Successful forecasts are highly dependent on the timeliness, accuracy, and quality of the initial data input. Weather personnel rely on constant feedback from updated weather collections of actual conditions to improve their forecasts. The use of AI streamlines the prediction process and boost accuracy and timeliness of weather forecasts.³⁶ AI can automate coding tasks, freeing up weather Airmen to focus on higher-level analysis and problem-solving. ML facilitates quicker updates and improvements to weather forecasting accuracy by identifying subtle patterns within vast datasets that human analysts might overlook. These technologies amplify the capabilities of small weather teams, allowing them to achieve faster results than traditional means.³⁷

In H.R. 4016, the Department of Defense Appropriations Act, 2026, the USSF was appropriated \$29.1 billion in discretionary funding, including \$4.86 billion for Operation and Maintenance. Combined USAF and USSF budget totaled \$261 billion.³⁸

United States Navy

The Department of the Navy plays a crucial role in forecasting and national security. The Naval Meteorology and Oceanography Command is the operational arm of the National Oceanography Program for the U.S. Navy. Their mission is to define and apply the physical environment, from the bottom of the ocean to the stars, to ensure that the U.S. Navy has the freedom of action to deter aggression, maintain freedom of the seas and win wars.³⁹ The Naval Oceanographic Office (NAVOCEANO), the largest subordinate command within the Naval Meteorology and Oceanography Command, is responsible for providing oceanographic products and services to all elements of the DoD.⁴⁰

Defense Meteorological Satellite Program

The Defense Meteorological Satellite Program (DMSP) is a successful collaboration between NOAA and DOD. This program is currently managed by the United States Space Force (USSF). Although operated by USSF, the instruments and observational capabilities were developed to satisfy Navy information requirements. DMSP satellites are operated complementary to NOAA's polar-orbiting satellites. Together, these satellites provide the military with important environmental information used in planning and conducting U.S. military operations worldwide.

DMSP satellites provide critical observations to support NOAA's three- to seven-day operational weather forecasts, operational weather "nowcasting" in Alaska and polar regions, and environmental monitoring and prediction.⁴¹

³⁵ Air Force Doctrine Publication 3-59, Weather Operations 26 September 2025.
https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-59/3-59-AFDP-WEATHER-OPS.pdf

³⁶ *Id.*

³⁷ *Id.*

³⁸ Text - H.R.4016 - 119th Congress (2025-2026): Department of Defense Appropriations Act, 2026, H.R.4016, 119th Cong. (2025), <https://www.congress.gov/bill/119th-congress/house-bill/4016/text>.

³⁹ *Mission & Vision*. Naval Meteorology and Oceanography Command. <https://www.cnmoc.usff.navy.mil/About-Us/Mission-Vision/>

⁴⁰ *Mission*. Naval Meteorology and Oceanography Command. <https://www.cnmoc.usff.navy.mil/Our-Commands/Naval-Oceanographic-Office/Mission/>

⁴¹ *Defense Meteorological Satellite Program*. National Environmental Satellite, Data, and Information Service. <https://www.nesdis.noaa.gov/our-satellites/currently-flying/defense-meteorological-satellite-program>

The DMSP program traces its origins back to 1962 and was originally a classified program. Declassified in 1972, the program launched 19 satellites, 17 of which have been retired. The last DMSP satellite launched in 2014 (it was retired in 2016 due to a power failure) and the oldest satellite currently in operation was launched in 2006.⁴² Congress voted to terminate the DMSP program in 2015, necessitating the development of the Weather System Follow-on Microwave (WSF-M) to ensure that there was no gap in the data.⁴³ WSF-M was launched in 2024 and became operational in April 2025.⁴⁴ Given the advanced age of the satellites, the DMSP program is slated to end in September 2026.

In July 2025, the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center announced its intent stop processing and distributing DMSP data due to information technology and security concerns. This decision was reversed and will continue to provide data until original planned end-of-life at the end of September 2026.⁴⁵

On April 11, 2024, USSF launched the ML-1A Weather System Follow-on – Microwave (WSF-M) to polar orbit to augment key capabilities of the legacy DMSP program, and to provide time-sensitive, combat-relevant environmental data for joint warfighters conducting mission planning and operations globally. In April 2025, WSF-M became operational and in 2027 USSF will launch WSF-M2.⁴⁶

DoD Reliance on NOAA Satellites

NOAA is currently the only agency that operates weather satellites in the geostationary orbit. Although DoD currently owns several geostationary weather satellites, these satellites are part of older NOAA GOES series that have been deemed to be beyond their operational life spans.⁴⁷ NOAA transfers these obsolete satellites to DoD for no charge. The Space Force transitions GOES satellites to military use once NOAA lofts their replacements, to fill a gap in weather monitoring over the Indian Ocean and provide data to Indo-Pacific Command (INDOPACOM).⁴⁸ NOAA continues to operate and host these satellites for DoD and are compensated for the operational and hosting functions only. The only geostationary weather satellites on orbit over the U.S. are the GOES satellites owned and operated by NOAA. Without these satellites, DoD would not be able to receive the myriad weather products generated by NOAA satellites.⁴⁹

With polar orbiting satellites orbiting the Earth 14 times daily, three differently-timed orbits are needed to guarantee total global coverage daily providing real time weather data. The polar orbiting weather satellites in LEO require three satellite constellations in sun-synchronous orbits to

⁴² *WMO OSCAR | Satellite: DMSP-F17*, https://space.oscar.wmo.int/satellites/view/dmsp_f17.

⁴³ (July 20, 2025), https://www.ospo.noaa.gov/data/messages/2025/07/MSG_20250730_0015.html.

⁴⁴ *Id.*

⁴⁵ *Id.*

⁴⁶ *First USSF WSF-M satellite reaches operational acceptance, advances space-based Environment*. United States Space Force. <https://www.spaceforce.mil/News/Article-Display/Article/4165122/first-ussf-wsf-m-satellite-reaches-operational-acceptance-advances-space-based/>

⁴⁷ <https://media.defense.gov/2023/Feb/14/2003161820/-1/-1/1/EWS-G1%20FACTSHEET.PDF>.

⁴⁸ Theresa Hitchens, *Stormy weather: DoD faces dearth of data from planned NOAA cuts*, *Breaking Defense* (Aug. 29, 2025), <https://breakingdefense.com/2025/08/stormy-weather-dod-faces-dearth-of-data-from-planned-noaa-cuts/>.

⁴⁹ *Id.*

create a complete picture. A sun-synchronous orbit is a polar orbit in which satellites are in sync with the Sun. Matching Earth's rotation around the Sun, they always appear in the same position relative to our star.⁵⁰ This means they pass over the same spot on Earth at the same local time every day. DMSP operates in the early-morning orbit. NOAA's JPSS satellites operate in the afternoon orbit. And the European EUMETSAT satellites operate in the mid-morning orbit. Without the NOAA and European satellite orbits in mid-morning and afternoon, DoD would have 2/3 less weather data by which to base their forecasts.

⁵⁰ *Types of orbits*, Webb https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits.

Appendix A – GOES Instruments

Advanced Baseline Imager (ABI)

The ABI is the primary instrument on the GOES-R Series for imaging Earth’s weather, oceans and environment. As the mission critical payload, it provides more than 65 percent of all mission data products.⁵¹ ABI is a multi-channel passive imaging radiometer designed to observe the Western Hemisphere and provide variable area imagery and radiometric information of Earth’s surface, atmosphere and cloud cover.⁵² ABI views the Earth with 16 different spectral bands compared to five on the previous generation of GOES and has multiple scan modes.⁵³ Depending on the resolution, ABI can take images as quickly as every 30 seconds.⁵⁴ The following table shows the 30 observation products generated by the ABI.

<u>Aerosol detection (including smoke and dust)</u>	<u>Aerosol optical depth (AOD)</u>	<u>Aerosol particle size</u>
<u>Clear sky masks</u>	<u>Cloud layers/heights</u>	<u>Cloud and moisture imagery</u>
<u>Cloud optical depth</u>	<u>Cloud particle size distribution</u>	<u>Cloud top height</u>
<u>Cloud top phase</u>	<u>Cloud top pressure</u>	<u>Cloud top temperature</u>
<u>Derived motion winds</u>	<u>Derived stability indices</u>	<u>Downward shortwave radiation: surface</u>
<u>Fire/hot spot characterization</u>	<u>Land surface albedo</u>	<u>Land surface bidirectional reflectance factor</u>
<u>Land surface temperature (skin)</u>	<u>Legacy vertical moisture profile</u>	<u>Legacy vertical temperature profile</u>
<u>Radiances</u>	<u>Rainfall rate/QPE</u>	<u>Reflected shortwave radiation: (TOA)</u>
<u>Sea and lake ice: age</u>	<u>Sea and lake ice: concentration</u>	<u>Sea and lake ice: motion</u>
<u>Sea surface temperature (skin)</u>	<u>Snow cover</u>	<u>Total precipitable water</u>

*GOES-R Series Data Products*⁵⁵

Geostationary Lightning Mapper

The Geostationary Lightning Mapper is a single-channel, near-infrared optical transient detector that can detect the momentary changes in an optical scene, indicating the presence of lightning.⁵⁶ GLM measures total lightning (in-cloud, cloud-to-cloud and cloud-to-ground) activity continuously over the Americas and adjacent ocean regions with near-uniform spatial resolution of approximately 10 km.⁵⁷ GLM collects information such as the frequency, location and extent of

⁵¹ *ABI* | *GOES-R Series*, <https://www.goes-r.gov/spacesegment/abi.html>.

⁵² *Id.*

⁵³ *Id.*

⁵⁴ *Id.*

⁵⁵ *Products* | *GOES-R Series*, <https://www.goes-r.gov/products/overview.html>.

⁵⁶ *GLM* | *GOES-R Series*, <https://www.goes-r.gov/spacesegment/glm.html>.

⁵⁷ *Id.*

lightning discharges to identify intensifying thunderstorms and tropical cyclones.⁵⁸ Used in combination with radar, satellite data, and surface observations, total lightning data from GLM has great potential to increase lead time for severe thunderstorm and tornado warnings and reduce false alarm rates.⁵⁹ The GLM generates a single data product and detects the light emitted by lightning at the tops of clouds day and night and collects information such as the frequency, location, and extent of lightning discharges.⁶⁰

Extreme Ultraviolet and X-Ray Irradiance Sensors (EXIS)

The EXIS on the GOES-R Series satellites are critical to understanding and monitoring solar irradiance in the upper atmosphere, that is, the power and effect of the Sun's electromagnetic radiation per unit of area.⁶¹ EXIS is able to detect solar flares that could interrupt communications and reduce navigational accuracy, affecting satellites, high altitude airlines and power grids on Earth.⁶² There are two sensors on this instrument, the X-Ray Sensor (XRS) and the Extreme Ultraviolet Sensor (EUVS).⁶³ XRS monitors solar flares and helps predict solar proton events that can penetrate Earth's magnetic field. The XRS is important in monitoring X-ray input into the Earth's upper atmosphere and alerts scientists to X-ray flares that are strong enough to cause radio blackouts and aids in space weather predictions.⁶⁴ The EUVS measures changes in the solar extreme ultraviolet irradiance which drive upper atmospheric variability on all time scales. An excess of EUV radiation can result in radio blackouts of terrestrial high frequency communications at low latitudes.⁶⁵ Large solar flares increase the EUV energy deposited in the earth's upper atmosphere (thermosphere) which causes increased atmospheric drag on satellites in low Earth orbit.⁶⁶ There are two products generated by the EXIS Sensors - Solar flux: EUV and Solar flux: X-Ray.⁶⁷

Solar Ultraviolet Imager (SUVI)

The Solar Ultraviolet Imager is a telescope that monitors the Sun in the extreme ultraviolet wavelength range. By observing the Sun, SUVI is able to compile full disk solar images around the clock.⁶⁸ SUVI observes and characterizes complex active regions of the Sun, solar flares, and the eruptions of solar filaments which may give rise to coronal mass ejections.⁶⁹ Depending on the magnitude of a particular solar eruption, a geomagnetic storm can result that is powerful enough to disturb Earth's magnetic field. Such an event may impact power grids by tripping circuit breakers, disrupt communication and satellite data collection by causing short-wave radio interference and damage orbiting satellites and their electronics.⁷⁰ The product that is generated by SUVI is solar

⁵⁸ *Id.*

⁵⁹ *Id.*

⁶⁰ *Data Products: Lightning Detection: Events, Groups & Flashes*, GOES-R Series <https://www.goes-r.gov/products/baseline-lightning-detection.html>.

⁶¹ *EXIS | GOES-R Series*, <https://www.goes-r.gov/spacesegment/exis.html>.

⁶² *Id.*

⁶³ *Id.*

⁶⁴ *Id.*

⁶⁵ *Id.*

⁶⁶ *Id.*

⁶⁷ *Id.*

⁶⁸ *SUVI | GOES-R Series*, <https://www.goes-r.gov/spacesegment/suvi.html>.

⁶⁹ *Id.*

⁷⁰ *Id.*

extreme ultraviolet imagery.⁷¹

Compact Coronagraph (CCOR)

Only the GOES-U satellite will accommodate an additional space weather instrument, the Naval Research Laboratory's Compact Coronagraph-1 (CCOR-1).⁷² The CCOR will image the solar corona (the outer layer of the Sun's atmosphere) and help detect and characterize CMEs.⁷³ Sequences of CME images can be used to determine size, velocity, and density of CMEs. CME imagery is currently the only source of 1+ day watches of impending geomagnetic storm conditions.⁷⁴ CCOR's primary data product is coronal white light intensity from which NOAA's Space Weather Prediction Center (SWPC) can perform CME characterization.⁷⁵

Space Environment In-Site Suite (SEISS)

The SEISS is comprised of four sensors that monitor proton, electron, and heavy ion fluxes in the magnetosphere.⁷⁶ The information provided by SEISS is critical for assessing the electrostatic discharge (ESD) risk and radiation hazard to astronauts and satellites.⁷⁷ In addition to hazard assessment, the information from SEISS can be used to warn of high flux events, mitigating any damage to radio communication.⁷⁸ The SEISS instrument suite consists of: the Energetic Heavy Ion Sensor (EHIS), the Magnetospheric Particle Sensors - High and Low (MPS-HI and MPS-LO), and the Solar and Galactic Proton Sensor (SGPS). The instrument suite also includes the Data Processing Unit (DPU).⁷⁹ The following table shows the four data products generated by SEISS.

<u>Energetic Heavy Ions</u>	<u>Magnetosphere electrons and protons: low energy</u>
<u>Magnetosphere electrons and protons: med and high energy</u>	<u>Solar and galactic protons</u>

*GOES-R Series Data Products*⁸⁰

Magnetometer (MAG)

The GOES-R Series Magnetometer (MAG) provides measurements of the space environment magnetic field that controls charged particle dynamics in the outer region of the magnetosphere.⁸¹ These particles can be dangerous to spacecraft and human spaceflight. MAG products are an integral part of NOAA's space weather operations, providing information on the general level of

⁷¹ *Products* | *GOES-R Series*, <https://www.goes-r.gov/products/overview.html>.

⁷² *CCOR* | *GOES-R Series*, <https://www.goes-r.gov/spacesegment/CCOR.html>.

⁷³ *Id.*

⁷⁴ *Id.*

⁷⁵ *CCOR* | *GOES-R Series*, <https://www.goes-r.gov/spacesegment/CCOR.html>.

⁷⁶ *SEISS* | *GOES-R Series*, <https://www.goes-r.gov/spacesegment/seiss.html>.

⁷⁷ *Id.*

⁷⁸ *Id.*

⁷⁹ *Id.*

⁸⁰ *Products* | *GOES-R Series*, <https://www.goes-r.gov/products/overview.html>.

⁸¹ *MAG* | *GOES-R Series*, <https://www.goes-r.gov/spacesegment/mag.html>.

geomagnetic activity and permitting detection of sudden magnetic storms.⁸² In addition, measurements can be used to validate large-scale space environment models that are used in operations.⁸³ The geomagnetic field product monitors changes in the Earth's geomagnetic field in three-dimensional space. These measurements are used to determine when magnetopause crossings occur, which is important sign of the arrival of some major space weather events, such as CMEs.⁸⁴

⁸² *Id.*

⁸³ *Id.*

⁸⁴ *Data Products: Geomagnetic Field | GOES-R Series*, <https://www.goes-r.gov/products/baseline-geomagnetic-field.html>.

Appendix B – Instruments on JPSS satellites

Advanced Technology Microwave Sounder (ATMS)

The ATMS provides information about the physical properties of our atmosphere, such as temperature and moisture, which heavily influence weather patterns. ATMS observes Earth in the microwave portion of the electromagnetic spectrum, which allows it to see through clouds.⁸⁵ Together, CrIS and ATMS primarily provide data on the water cycle, which includes water vapor, clouds and precipitation.⁸⁶ Because clouds are opaque in the infrared part of the spectrum (measured by the CrIS instrument) and largely transparent at microwave frequencies (measured by ATMS), operating these two instruments together makes it possible to cover a broader range of weather conditions.⁸⁷ ATMS provides a view inside and below clouds and can be used to produce images inside storms, including hurricanes.⁸⁸ This provides invaluable data for understanding storms and making predictions up to five to seven days in advance of a severe weather event.⁸⁹

Clouds and Earth's Radiant Energy System (CERES)

Measurements from the CERES instrument help scientists understand the links between the energy being absorbed and emitted by Earth's climate, and the properties of the atmosphere (like clouds) that affect that energy balance.⁹⁰ The observations from CERES help measure the effect of clouds on Earth's energy balance, which strongly influences both weather and climate.⁹¹ CERES' global observations provide data for improving seasonal climate forecasts, including cloud and radiative aspects of large-scale climate events like El Niño and La Niña.⁹²

Cross-track Infrared Sounder (CrIS)

The CrIS instrument provides more accurate, detailed atmospheric temperature and moisture observations for weather and climate applications.⁹³ CrIS works best in clear to partly cloudy conditions because infrared energy doesn't penetrate thick clouds.⁹⁴ For this reason, CrIS works in tandem with the Advanced Technology Microwave Sounder (ATMS), since microwave energy from this instrument *can* penetrate most cloud cover.⁹⁵ A sounding is a measurement that provides a vertical profile, or information about how something (temperature, water vapor, ozone) changes

⁸⁵ *Advanced Technology Microwave Sounder (ATMS)*, National Environmental Satellite, Data, and Inform <https://www.nesdis.noaa.gov/our-satellites/currently-flying/joint-polar-satellite-system/advanced-technology-microwave-sounder-atms>.

⁸⁶ *Id.*

⁸⁷ *Id.*

⁸⁸ *Id.*

⁸⁹ *Id.*

⁹⁰ *Clouds and the Earth's Radiant Energy System (CERES)*, National Environmental Satellite, Data, and Inform <https://www.nesdis.noaa.gov/our-satellites/currently-flying/joint-polar-satellite-system/clouds-and-the-earths-radiant-energy-system-ceres>.

⁹¹ *Id.*

⁹² *Id.*

⁹³ *Cross-track Infrared Sounder (CrIS)*, National Environmental Satellite, Data, and Inform <https://www.nesdis.noaa.gov/our-satellites/currently-flying/joint-polar-satellite-system/cross-track-infrared-sounder-cris>.

⁹⁴ *Id.*

⁹⁵ *Id.*

with altitude.⁹⁶ An infrared sounder scans the Earth's surface as the instrument passes overhead, measuring the infrared spectrum emitted from the surface and atmosphere.⁹⁷ The infrared spectrum is then converted into 3D measurements of temperature and water vapor throughout the different levels of the atmosphere.⁹⁸

Ozone Mapping and Profiler Suite (OMPS)

The OMPS tracks the health of the ozone layer and measures the concentration of ozone and other aerosols in the Earth's atmosphere.⁹⁹ Though ozone measurement is the primary purpose of OMPS, it also measures other atmospheric trace species like sulfur dioxide and ash that result from volcanic eruptions.¹⁰⁰ These measurements are helpful in providing aircraft safety warnings. OMPS measurements also fulfill the U.S. treaty obligation to monitor global ozone concentrations for the Montreal Protocol to ensure there are no gaps in coverage.¹⁰¹

Visible Infrared Imaging Radiometer Suite (VIIRS)

The VIIRS instrument collects visible and infrared images and global observations of the land, atmosphere, cryosphere and oceans.¹⁰² Currently flying on the Suomi NPP and NOAA-20 satellite missions, VIIRS instruments generate many critical environmental products pertaining to snow and ice cover, clouds, fog, aerosols, fire, smoke plumes, dust, vegetation health, phytoplankton abundance and chlorophyll.¹⁰³ VIIRS produces higher-resolution and more accurate measurements of sea surface temperature, as well as an operational capability for ocean color observations and products.¹⁰⁴ Ocean color is a key indicator of water quality and supports decisions ranging from fisheries management to tourism.¹⁰⁵

⁹⁶ *Id.*

⁹⁷ *Id.*

⁹⁸ *Id.*

⁹⁹ *Ozone Mapping and Profiler Suite (OMPS)*, National Environmental Satellite, Data, and Inform <https://www.nesdis.noaa.gov/our-satellites/currently-flying/joint-polar-satellite-system/ozone-mapping-and-profiler-suite-omps>.

¹⁰⁰ *Id.*

¹⁰¹ *Id.*

¹⁰² *Visible Infrared Imaging Radiometer Suite (VIIRS)*, National Environmental Satellite, Data, and Inform <https://www.nesdis.noaa.gov/our-satellites/currently-flying/joint-polar-satellite-system/visible-infrared-imaging-radiometer-suite-viirs>.

¹⁰³ *Id.*

¹⁰⁴ *Id.*

¹⁰⁵ *Id.*