NOAA Space Weather

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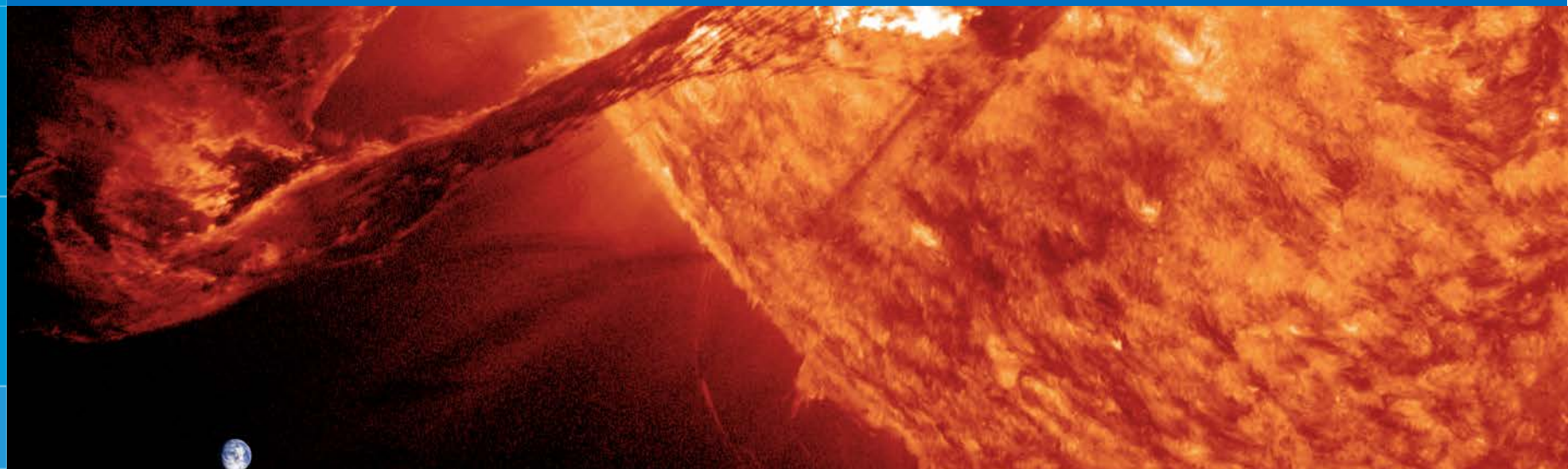


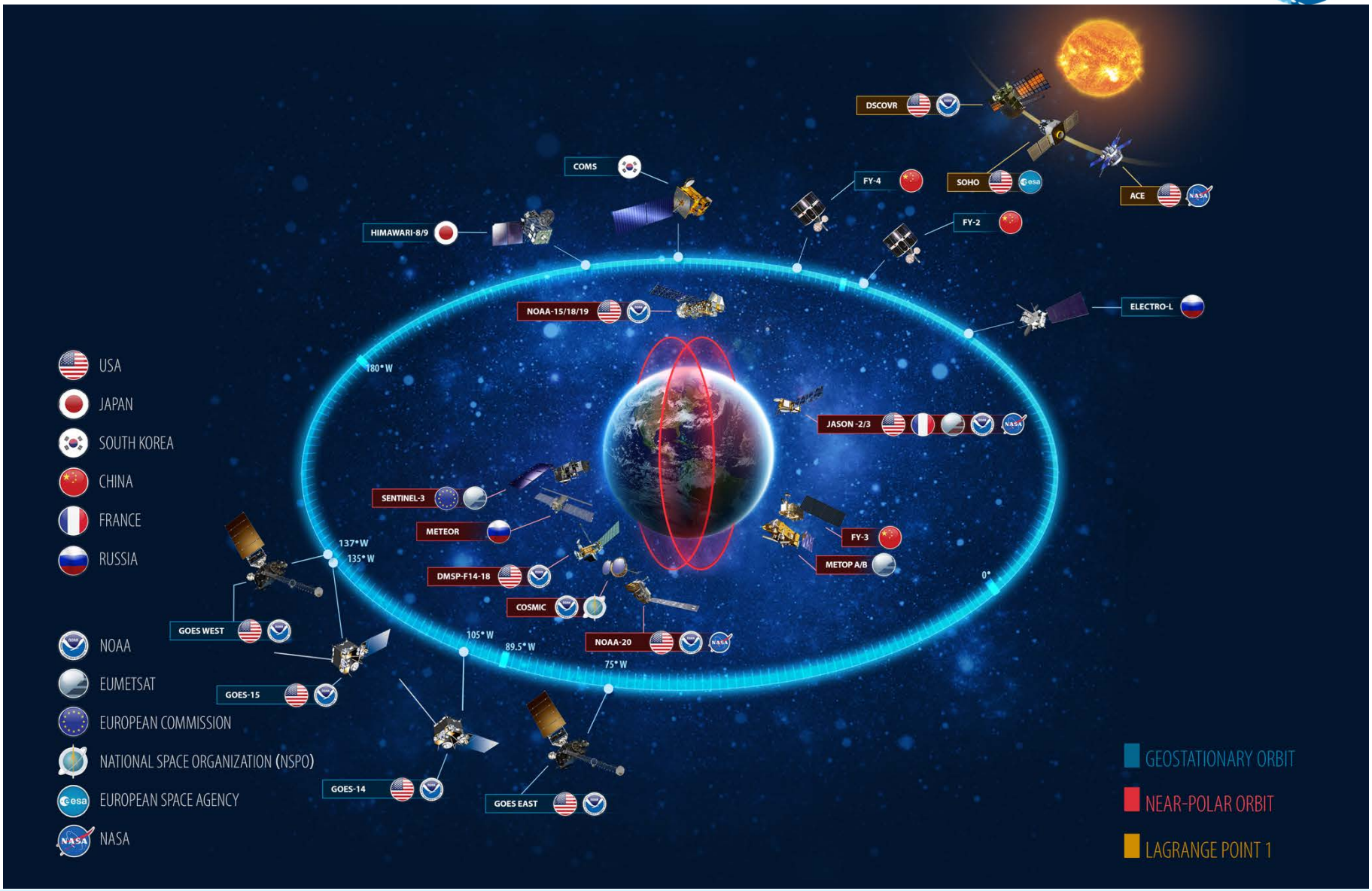
Coordination Group for Meteorological Satellites

- CGMS - is the group for global coordination of meteorological satellite systems.
  - Includes protection of in orbit assets, contingency planning, improvement of quality of data, support to users, facilitation of shared data access and development of the use of satellite products in key application areas.
  - Coordination is pursued from an end-to-end perspective between meteorological satellite operators and user communities such as WMO, IOC-UNESCO and others.
- High-level space weather goals:
  - Improve the near-real-time access to and global exchange of space weather data from instruments on meteorological satellites
  - Identify baseline space-based space weather observational system for the WMO 2040 vision for global observing system
  - Establish coordinated spacecraft anomaly reporting
  - Evaluate operational space weather products in support of CGMS spacecraft operations, and recommend needed services

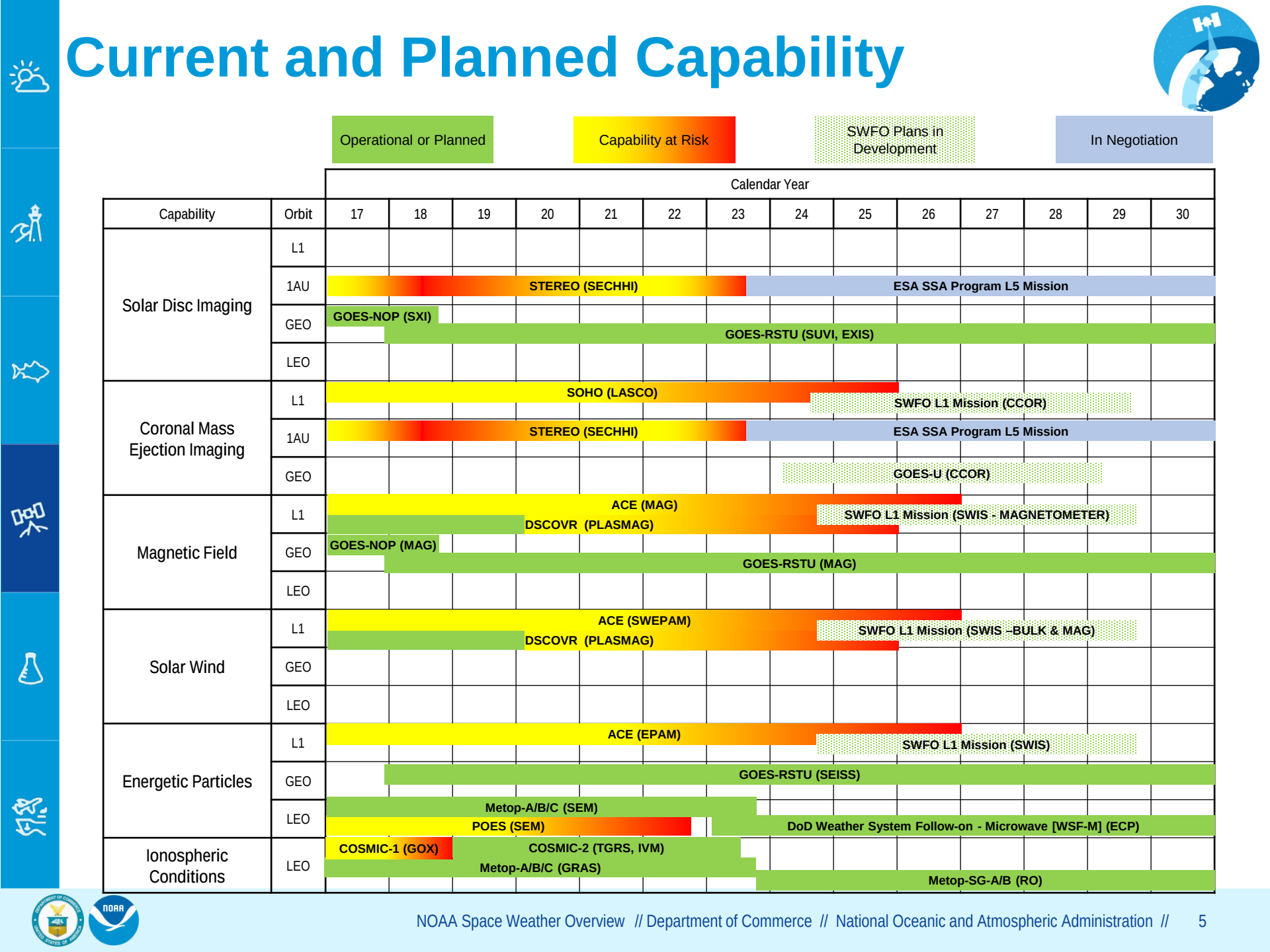
2018 CGMS Space Weather Update

- **New Terms of Reference for Space Weather.** Approved by the Plenary and now be called the Space Weather Coordination Group giving this group permanent status for the first time.
- **CGMS Baseline and Contingency Plan.** The updated Baseline and Contingency Plan were approved by the Plenary. The Baseline now designed to reflect the commitments of CGMS Members and captures space weather observations and measurements for the first time.
- Space Weather Calibration
- Space Weather Anomalies

Space Weather – Global Effort



Current and Planned Capability



Observations and Measurements

- **Low-Earth Orbit**: In-situ measurements provided by instruments on LEO satellites, and GNSS radio occultation measurements providing total electron content, produce the current state of ionosphere

- **Geostationary Orbit:** In-situ measurements of the space environment and the magnetic field of the magnetosphere provide advanced warning of space weather events. Imaging of the Sun in the x-ray and ultraviolet bands allow detection of solar flares, which supports forecasting; Coronagraph imaging of the Sun for CMEs provides 1-4 day advanced warning of geomagnetic storms

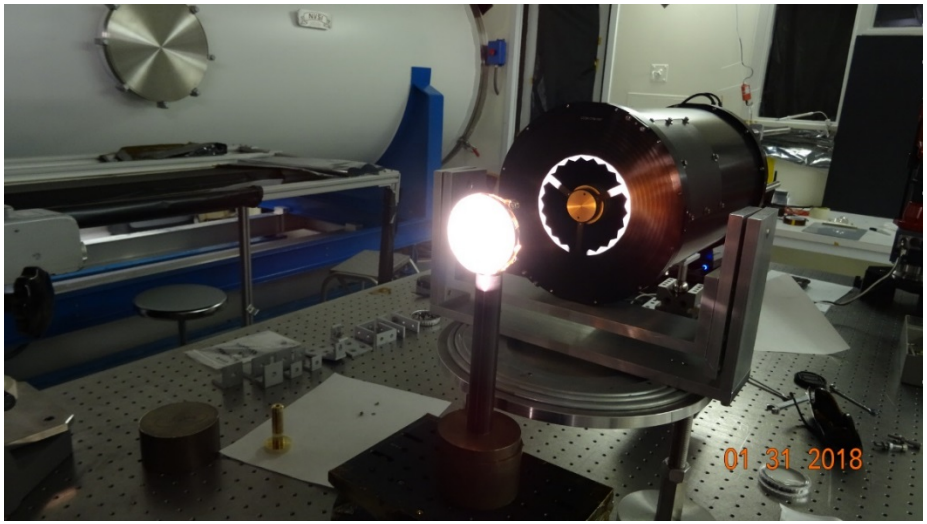
- **L1:** In-situ measurement of the solar wind speed and magnetic field provides 15-60 minutes of advanced warning of arrival at Earth; Coronagraph imaging of the Sun for CMEs provides 1-4 day advanced warning of geomagnetic storms

- **L5:** Enhanced performance may be obtained by a potential ESA L5 mission that support forecasting and complementary measurements by providing an “off-axis” view of the Sun. Mission gives visibility of the propagation of plasma clouds from the Sun towards Earth as well as view of the solar disk before it rotates into view from Earth

NOAA NESDIS Space Weather Platform Status - CCOR

CCOR: NOAA's first operational coronagraph

Presently using NASA/ESA SOHO CME images to define the inner boundary of the CME propagation code WSA/Enlil (1-4 day warnings of Earth arrival)

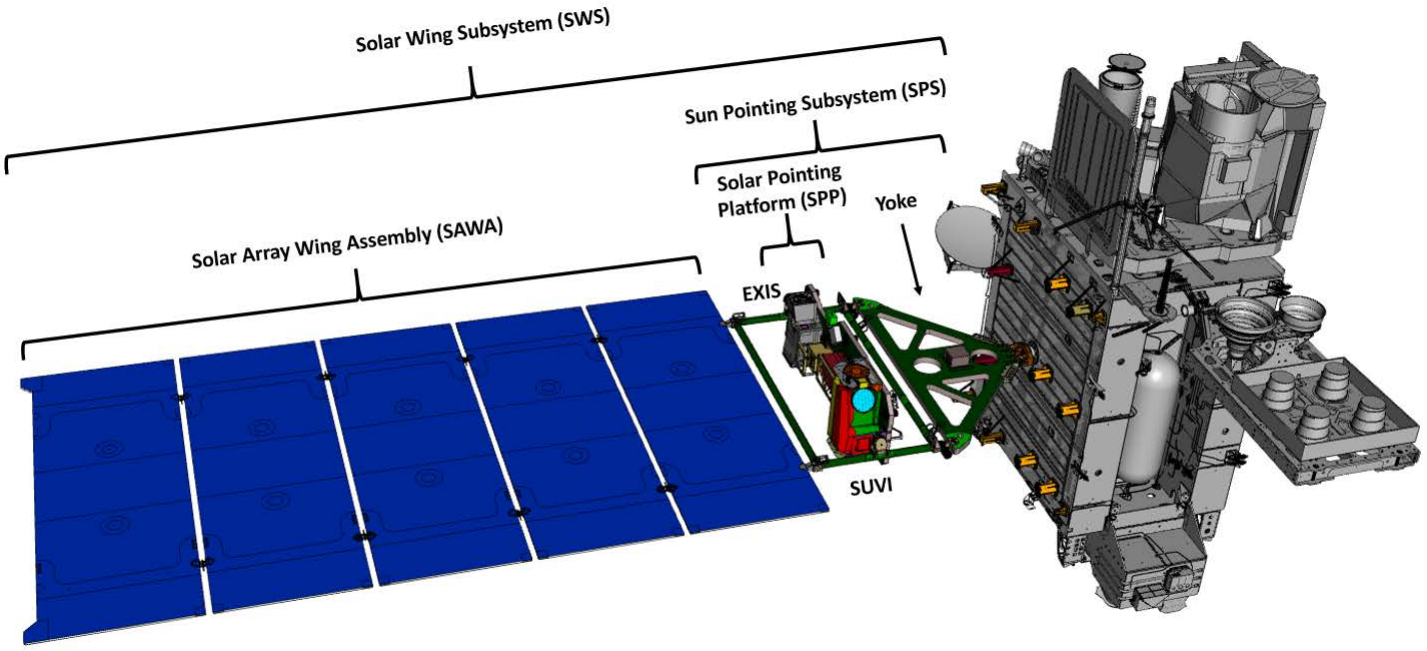


CCOR Optical Testbed- Initial Illumination Test

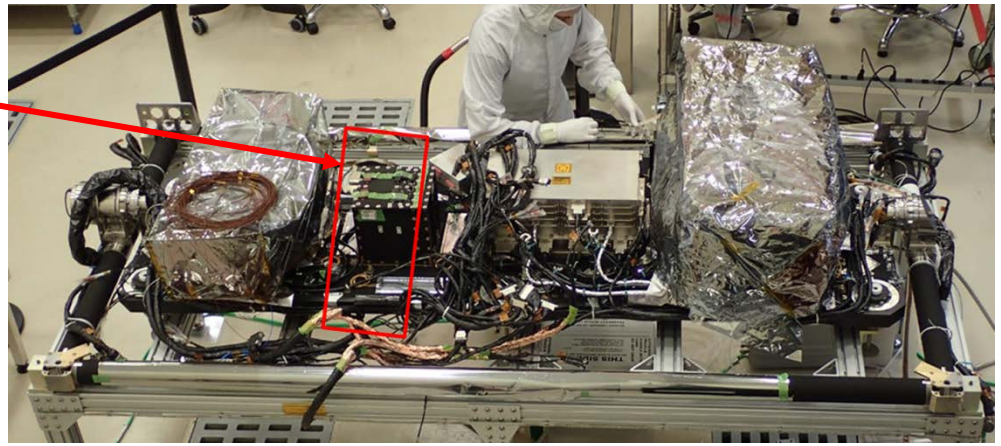
CCOR In Phase B; NRL Preliminary Design Review 9/28/18

Possible deployment on GOES U 2024

Current GOES-R Configuration



Area for CCOR



NOAA Space Weather Follow On Plan Summary

- Establish and sustain a foundational set of space-based observations and measurements (i.e., CME imaging and solar wind measurements)

- Ensure continuity of critical data
  - Complete the Compact Coronagraph (CCOR) with Naval Research Laboratory (NRL) as NOAA partner project.
  - Host CCOR on the GOES-U spacecraft planned for launch in early 2024
  - Establish new acquisition of Space Weather Instrument Suite (SWIS)
  - Establish new acquisition of NOAA spacecraft and NOAA/NASA partnership for launch rideshare to L1 with NASA's Interstellar Mapping and Acceleration Probe (IMAP) late 2024. NOAA L1 spacecraft will have SWIS, CCOR and instruments of opportunity
  - NOAA Satellite Observing System Architecture (NSOSA) calls for sustained Space Weather in-situ and CME capability

- Maintain archives for space-based data which are essential for model development and benchmarking

Backup

DOC Space Traffic Management

- **Space Policy Directive-3**: “Department of Commerce should be the new civil agency interface for space traffic management (STM) and space situational awareness (SSA)”

- Space Weather situational awareness is critical when assessing the natural environment occupied by the increasing government and commercial space activity, which will soon include space tourism

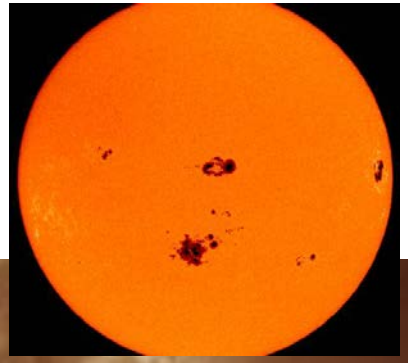
- Space weather services contribute to the following goals of STM:
  - Mitigate the effect of orbital debris on space activities (*actionable collision avoidance warnings require space weather information*)
  - Encourage and facilitate U.S. commercial leadership in S&T, SSA, and STM
  - Provide U.S. Government-supported basic SSA data and basic STM services to the public
  - Improve SSA data interoperability and enable greater SSA data sharing

Space Weather

Space Weather: The impact of solar wind and solar storms on Earth's environment

Causes of space weather:

- Radio and X-Ray flux
- Coronal Mass Ejection (CME)
- Variation in Solar Wind



Impact of Space Weather:

- Navigation and timing interference(including GPS)
- Geomagnetically induced currents in electric power grid, rail systems, and pipelines
- Satellite drag, interference, and degradation
- Radiation exposure to astronauts and to passengers and crew in aircraft

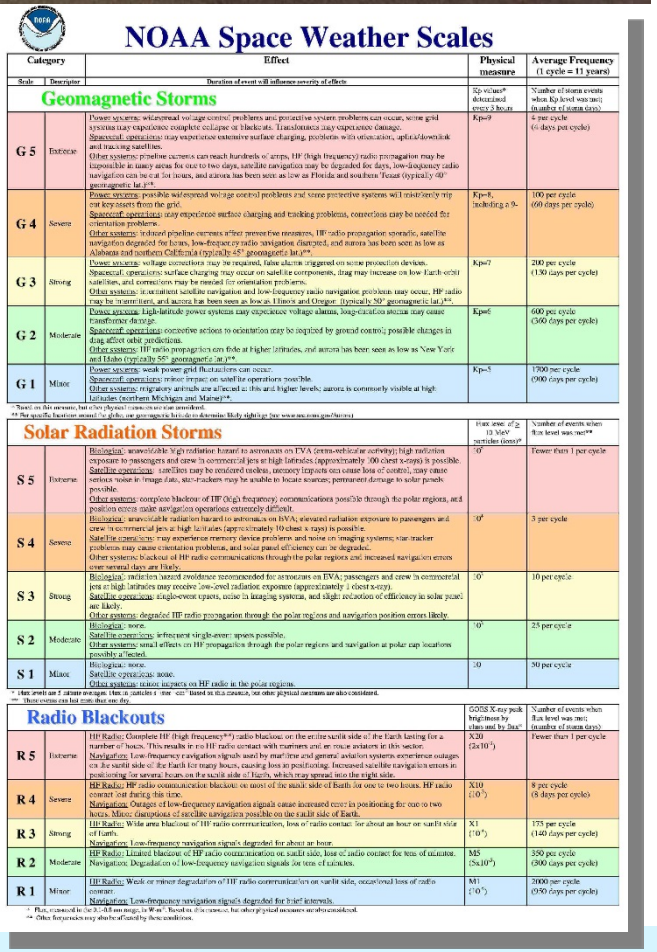
NOAA Space Weather Prediction Center

Department of Commerce, through NOAA, provides 24/7 space weather services for the Nation

NOAA Space Weather Warnings are based on the NOAA Space Weather Scales:

- **Geomagnetic Storms (G-scale)** (Magnetic field)
- **Solar Radiation Storms (S-scale)** (Energetic charged particles)
- **Radio Blackouts (R-scale)** (Electromagnetic radiation)

DoD services provided by USAF 557th Weather Wing at Offutt AFB, NE



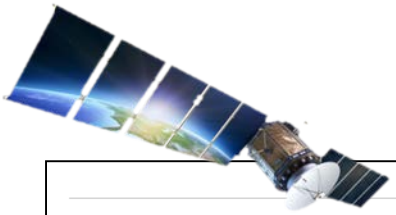
NOAA Space Weather Scales

Category		Effect	Physical measure	Average Frequency (1 cycle = 11 years)
Scale	Descriptor	Duration of event will influence severity of effects		
Geomagnetic Storms			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
G 5	Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.)**.	Kp=9	4 per cycle (4 days per cycle)
G 4	Severe	Power systems: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. Spacecraft operations may experience surface charging and tracking problems, corrections may be needed for orientation problems. Other systems: induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.)**.	Kp=8, including a 9-	100 per cycle (60 days per cycle)
G 3	Strong	Power systems: voltage corrections may be required, false alarms triggered on some protection devices. Spacecraft operations: surface charging may occur on satellite components, drag may increase on low Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.)**.	Kp=7	200 per cycle (130 days per cycle)
G 2	Moderate	Power systems: high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. Spacecraft operations: corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.)**.	Kp=6	600 per cycle (360 days per cycle)
G 1	Minor	Power systems: weak power grid fluctuations can occur. Spacecraft operations: minor impact on satellite operations possible. Other systems: migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine)**.	Kp=5	1700 per cycle (900 days per cycle)
* Based on this measure, but other physical measures are also considered. ** For specific locations around the globe, use geomagnetic latitude to determine. Map right (or see www.swpc.noaa.gov/noaa)				
Solar Radiation Storms			Flux level of ≥ 10 MeV particles (ions)*	Number of events when flux level was met**
S 5	Extreme	Biological: unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); high radiation exposure to passengers and crew in commercial jets at high latitudes (approximately 100 chest x-rays) is possible. Satellite operations: satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. Other systems: complete blackout of HF (High) frequency; communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5	Fewer than 1 per cycle
S 4	Severe	Biological: unavoidable radiation hazard to astronauts on EVA; elevated radiation exposure to passengers and crew in commercial jets at high latitudes (approximately 10 chest x rays) is possible. Satellite operations: may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. Other systems: blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	10^4	3 per cycle
S 3	Strong	Biological: radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in commercial jets at high latitudes may receive low-level radiation exposure (approximately 1 chest x-ray). Satellite operations: single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. Other systems: degraded HF radio propagation through the polar regions and navigation position errors likely.	10^3	10 per cycle
S 2	Moderate	Biological: none. Satellite operations: infrequent single-event upsets possible. Other systems: small effects on HF propagation through the polar regions and navigation at polar cap locations possibly affected.	10^2	25 per cycle
S 1	Minor	Biological: none. Satellite operations: none. Other systems: minor impacts on HF radio in the polar regions.	10	50 per cycle
* Flux levels are 5 minute averages. Units in particles / (cm² · sec · ster) based on this measure, but other physical measures are also considered. ** Multiple events can last more than one day.				
Radio Blackouts			GOES X-ray peak brightness by class and by flux*	Number of events when flux level was met; (number of storm days)
R 5	Extreme	HF Radio: Complete HF (high frequency**) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. Navigation: Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 ($2x10^{-3}$)	Fewer than 1 per cycle
R 4	Severe	HF Radio: HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. Navigation: Outages of low-frequency navigation signals cause increased errors in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10^{-3})	8 per cycle (8 days per cycle)
R 3	Strong	HF Radio: Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. Navigation: Low-frequency navigation signals degraded for about an hour.	X1 (10^{-4})	175 per cycle (140 days per cycle)
R 2	Moderate	HF Radio: Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes. Navigation: Degradation of low-frequency navigation signals for tens of minutes.	M5 ($5x10^{-5}$)	350 per cycle (300 days per cycle)
R 1	Minor	HF Radio: Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact. Navigation: Low-frequency navigation signals degraded for brief intervals.	M1 (10^{-5})	2000 per cycle (950 days per cycle)
* Flux, measured in the 1- to 8-Å X-ray range, in W·m⁻². Based on this measure, but other physical measures are also considered. ** Other frequencies may also be affected by these conditions.				

Uses of Space Weather Products

Space Operations

- Postpone launch of satellite
- Turn off/safe instruments and/or spacecraft in orbit



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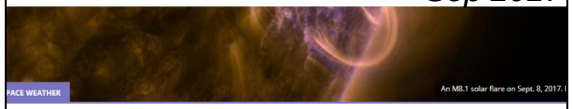
Electric Power Grid

- Adjust/reduce system load
- Disconnect components
- Postpone maintenance

MOTHERBOARD *Sep 2017*



Solar Flares Interfered With Radio Network's Ability to Warn People About Hurricane Irma

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by Tariq Malik, Managing Editor | January 08, 2014 08:10am ET

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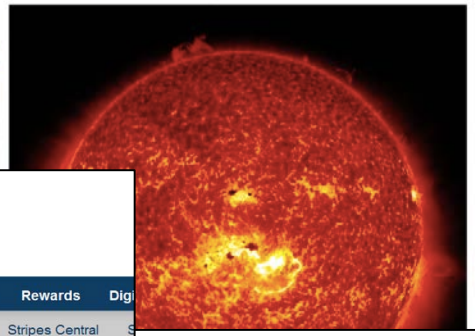

Airlines

- Divert polar flights
- Change altitude

GPS/Navigation

- Postpone activities
- Redo survey
- Use backup systems

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