



# NOAA's Current and Future Space Weather Architecture



NOAA Satellite and  
Information Service  
[www.nesdis.noaa.gov](http://www.nesdis.noaa.gov)

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**Dr. Elsayed Talaat**  
**Director, Office of Projects, Planning, and Analysis**

**Infrastructure Workshop, National Academies of Science, Engineering and Medicine**

# NOAA Space Weather Prediction Center



- The Nation's official source of space weather alerts, watches and warnings
- Provides 24x7 analysis and forecasting of space weather storms

NOAA Space Weather Watches and 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)

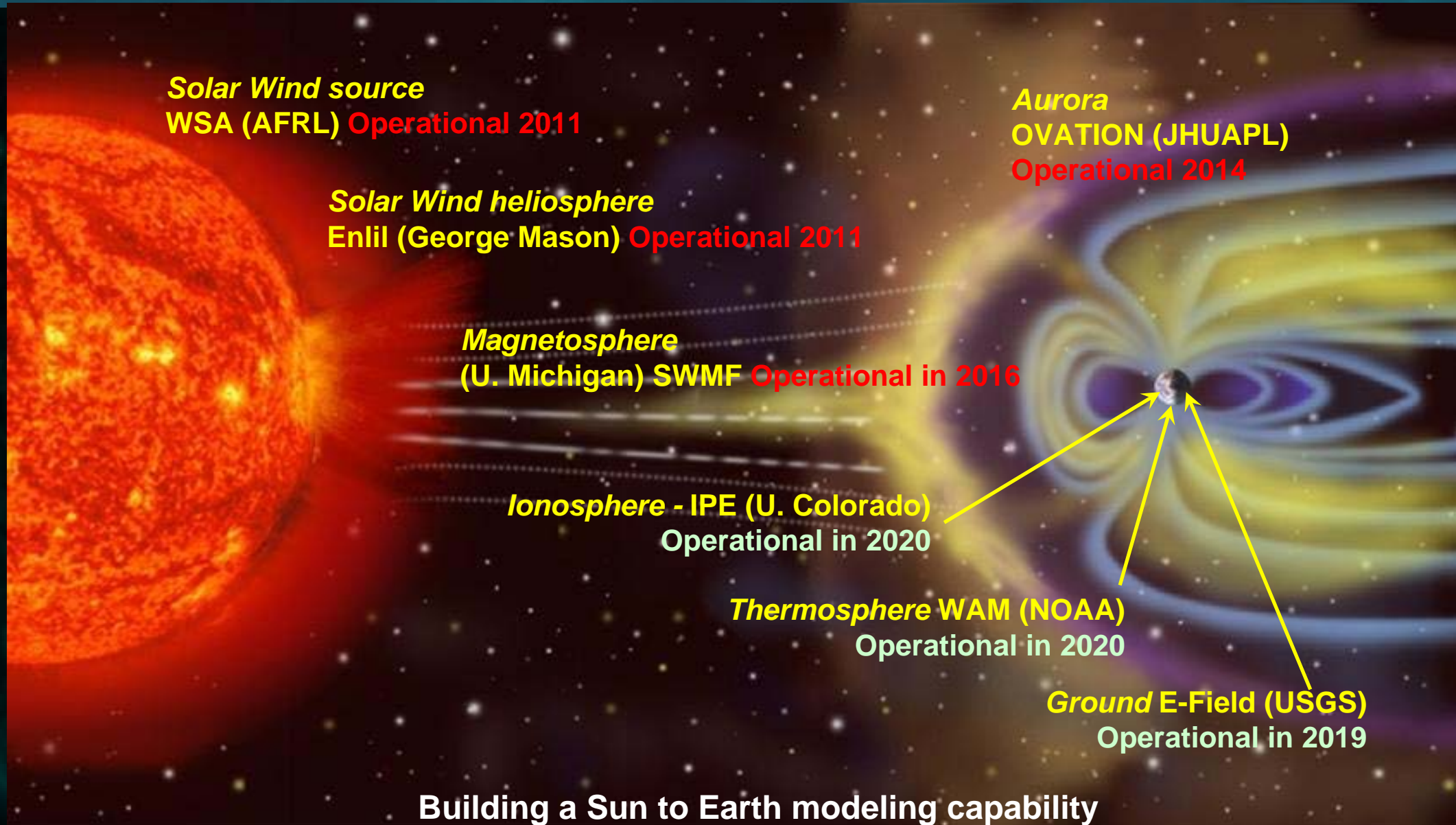
DoD services provided by  
USAF 557th Weather Wing

NOAA Space Weather Scales				
Category	Effect	Physical measure	Avg. frequency	Number of events when forecast was correct
Scale	Description	Definition of event and influence severity of effects		
<b>Geomagnetic Storms</b>				
G5	Extreme	Power systems, without surge control, experience system problems that cause some grid components to experience complete collapse in blackouts. Launches and operations damage. Structural degradation may experience extensive surface charging, problems with vibration, optical distortion 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 on local, national, and global scales has been seen as low as 10% and southern Total Electron Content (TEC) greater than 10 <sup>19</sup> m <sup>-2</sup> .	10 <sup>-4</sup> W/m <sup>2</sup> (at 100 kHz) or more Kp=9 4 per cycle (4 days per cycle)	5 number of events when forecast was correct (number of events)
G4	Severe	Power systems, without surge control, experience system problems and some protective systems will malfunction. Key systems may experience surface charging and tracking problems, corrections may be needed for navigation problems. Other systems: pipeline currents may 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 on local, national, and global scales has been seen as low as 10% and southern Total Electron Content (TEC) greater than 10 <sup>19</sup> m <sup>-2</sup> .	Kp=8, building to 9 100 per cycle (60 days per cycle)	
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G2	Moderate	Power systems, without surge control, may experience system problems and some protective systems will malfunction. Key systems may experience surface charging and tracking problems, corrections may be needed for navigation problems. Other systems: pipeline currents may 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 on local, national, and global scales has been seen as low as 10% and southern Total Electron Content (TEC) greater than 10 <sup>19</sup> m <sup>-2</sup> .	Kp=6 600 per cycle (500 days per cycle)	
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<b>Solar Radiation Storms</b>				
S5	Extreme	Background: severe solar radiation storm in the solar wind, high radiation exposure to passengers and crew is estimated at 100 mSv (10000 mrem) in 10 minutes. Satellite operations: satellites may be rendered useless, accuracy degrades, cause loss of control, may cause serious damage to payload, and/or cause permanent damage to solar panels. Other systems: complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10 <sup>-4</sup> W/m <sup>2</sup> (at 100 kHz) or more Kp=9 4 per cycle (4 days per cycle)	5 number of events when forecast was correct (number of events)
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<b>Radio Blackouts</b>				
R5	Extreme	HF Radio: Complete HF (high frequency) radio blackout, on the sunlit side of the Earth lasting for a number of hours. This results in a HF radio contact with stations and/or in a station in this sector. Background: Low-frequency navigation signals used by many civil and military systems experience complete degradation on the sunlit side of the Earth for many hours, causing loss of positioning. Increased satellite navigation errors in positioning in severe hours on the sunlit side of the Earth, which may spread into the night side. HF Radio: HF radio communication blackouts on some of the sunlit side of the Earth for one to two hours. HF radio contact lost during this time. HF Radio: Widespread blackouts of HF radio communication on the sunlit side of the Earth for one to two hours. HF radio contact lost during this time. Background: Low-frequency navigation signals degraded for about an hour.	10 <sup>-4</sup> W/m <sup>2</sup> (at 100 kHz) or more Kp=9 4 per cycle (4 days per cycle)	5 number of events when forecast was correct (number of events)
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# NOAA Space Weather Modeling



# Pillars of NESDIS Observing System Implementation

## Integrated, Adaptable and Affordable: Orbits, Instruments & Systems

### GEO

Continuous real-time observations supporting warnings and watches of severe weather and hour-by-hour changes. High-inclination orbits to observe northern latitude & polar regions.

### LEO

Miniaturized instruments on small, affordable and proliferated satellites and partner data improving forecasts through better and additional data. Better precipitation forecasts, wave height predictions, ocean currents, and more.

### Space Weather

Reliably monitoring space weather from L1, GEO and LEO can protect the nation's valuable, vulnerable infrastructure. New capabilities at L5 and HEO can provide additional insight and improve forecasts.

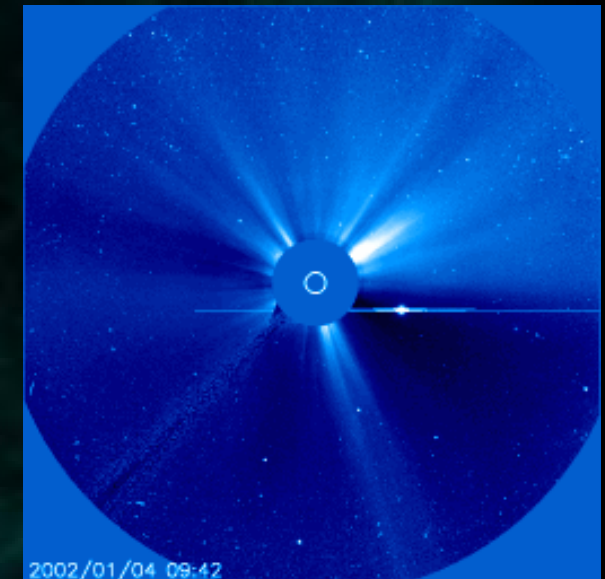
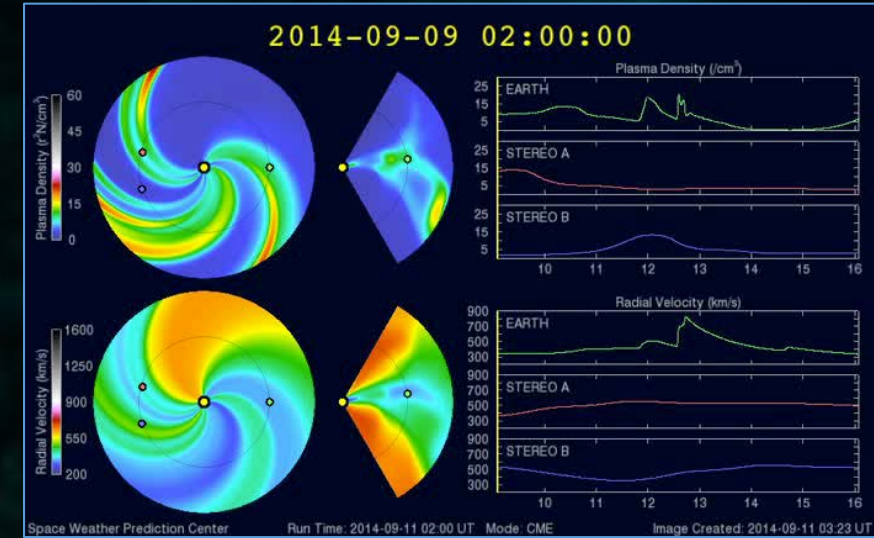
### Common Ground Services

Secure ingest of data in different formats from different partners requires a flexible, scalable platform. Common Services approach integrates Cloud, AI and machine-learning capabilities to verify, calibrate and fuse data into new and better products and services.



# Solar Wind and CME Imagery for Space Weather Prediction

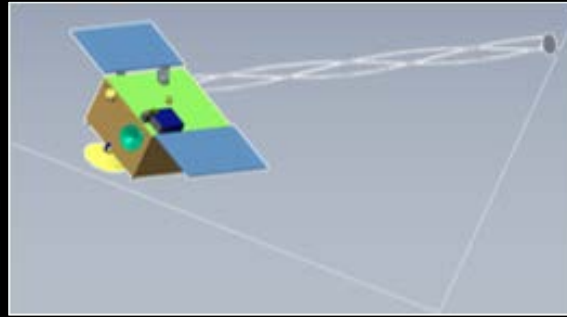
- The NWS Space Weather Prediction Center (SWPC) is the nation's official source of space weather Watches, Warnings and Alerts.
- Coronal Mass Ejection (CME) Imagery
  - Visible light imagery of CMEs used for 1-4 day warnings of geomagnetic storm conditions
  - Primary source: ESA/NASA Solar and Heliophysics Observatory (SOHO, 1995) - solar power limited to 2025
  - Backup: \*none\*
- Solar Wind In-Situ at Sun-Earth Lagrange – L1
  - Solar wind magnetic field and bulk plasma provide 15-60 minute warning of geomagnetic storm conditions
  - Primary source: NOAA/Deep Space Climate Observatory (DSCOVR), launch 2015
  - Backup: NASA Advanced Composition Explorer (ACE) launch 1997 – propulsion limited to 2026



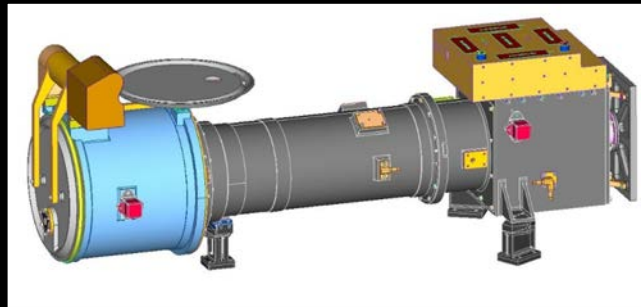


# SWFO Program Key Technical Components

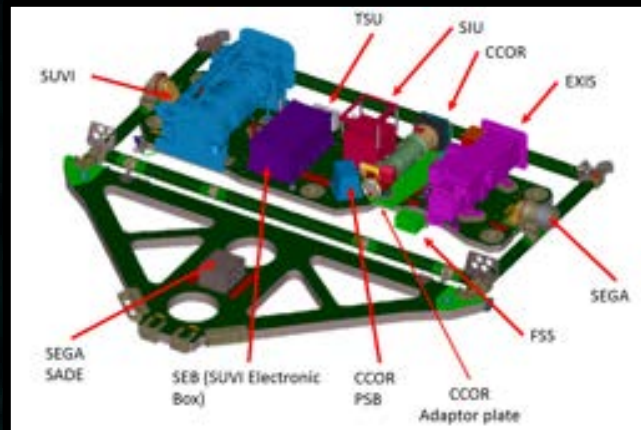
3-Axis  
Stabilized ESPA  
Class  
Spacecraft



Compact  
Coronagraph  
(CCOR)



GOES-U Solar Pointing Platform (SPP)



CCOR +  
SUVI +  
EXIS

## SWFO-L1 Mission Overview

- Space Weather Operational Observation at Earth-Sun Lagrange Point 1
- IAA with NASA to procure an ESPA Grande compatible spacecraft
- SWIS (Solar Wind Instrument Suite) awards nearly complete, CCOR in Phase D
- NOAA ground services
- Rideshare with NASA IMAP
- Nominal launch: 2024
- Potential ESA contributed instrument (X-Ray flux monitor)

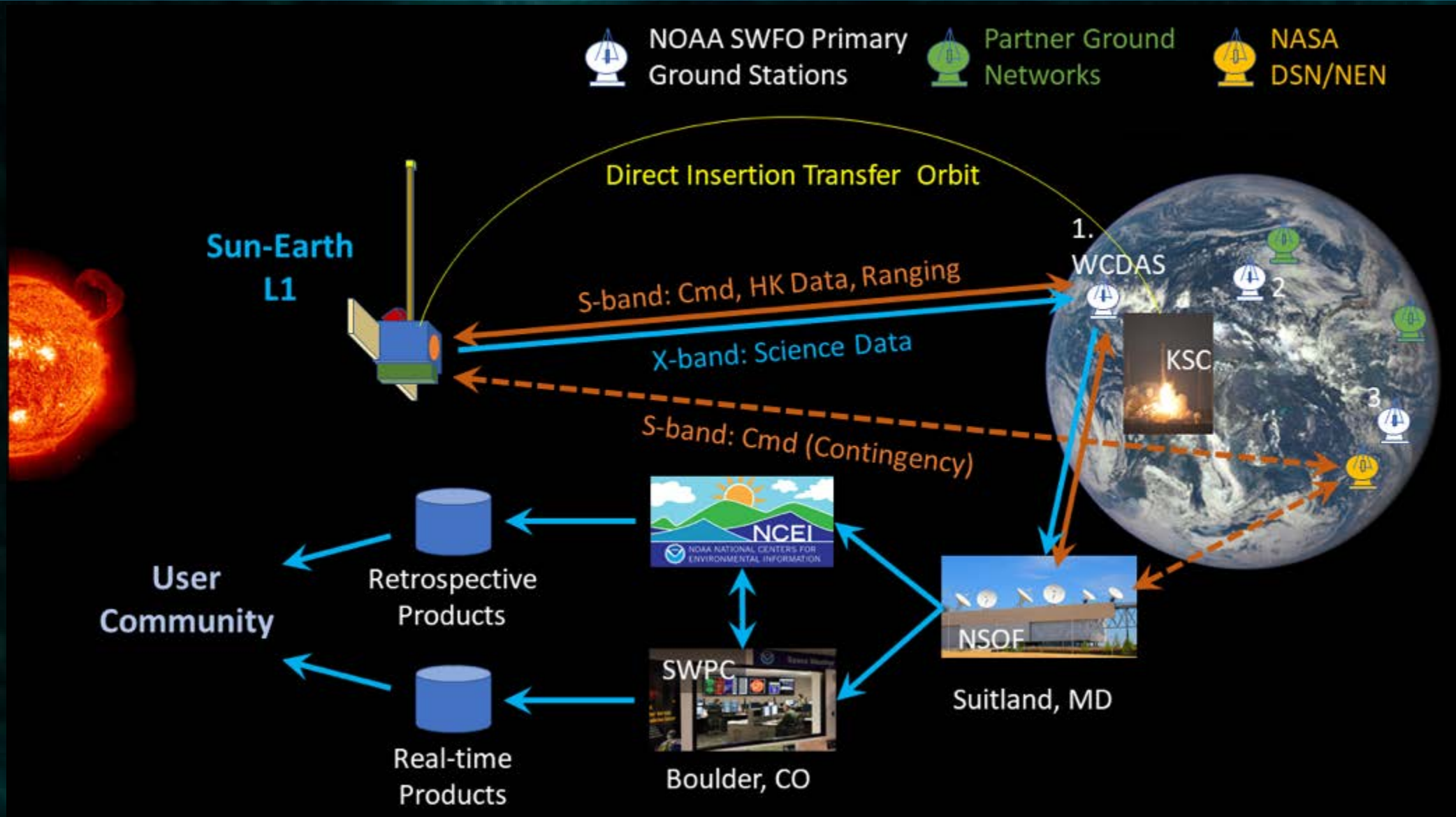
## Coronagraph Project

- Compact Coronagraphs under development by NRL via an IAA
- CCOR for SWFO-L1 Satellite, deliver 2022
- CCOR for GOES-U, deliver 2021
- Potential CCOR for ESA-L5 Satellite, deliver 2023

## Coronagraph Accommodation on GOES-U

CME imaging from geostationary orbit  
CCOR Integrated onto GOES-U SPP  
Commanding and data flow through GOES-R ground services  
Nominal launch: 2024

# SWFO Mission Architecture



# NOAA – in the last two years ...

## Established the baseline operational Space Weather Follow On (SWFO) Program

- Secured funding in the NOAA budget for L1 coverage
- Begun flight fabrication of the Compact CORonagraph (CCOR) with NRL
- Secured funding in the NOAA budget for CCOR on GOES-U
- Established a joint project office with NASA for SWFO
- Established an agreement with the NASA IMAP mission for a rideshare for SWFO-L1
- Let procurement RFPs for instruments
- Formulated arrangements with ESA for data sharing with the L5 mission
- Negotiating with ESA for instrument exchanges

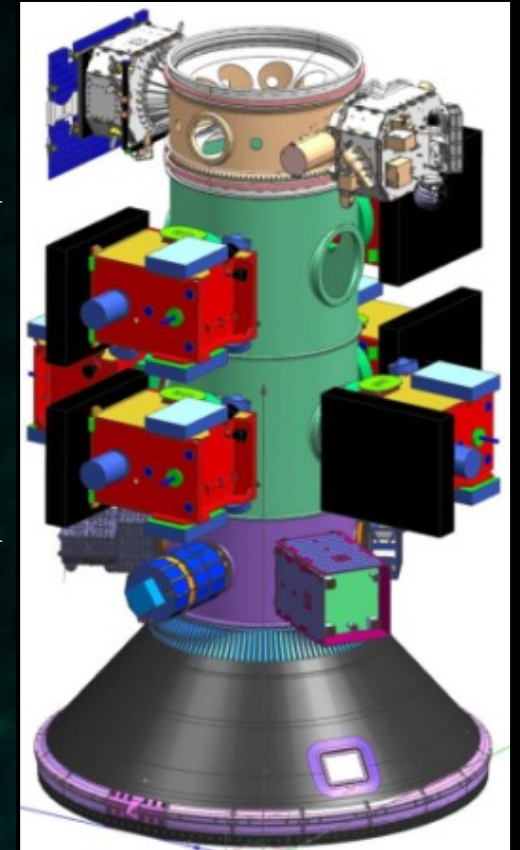
Launched the COSMIC-2 mission with Taiwan



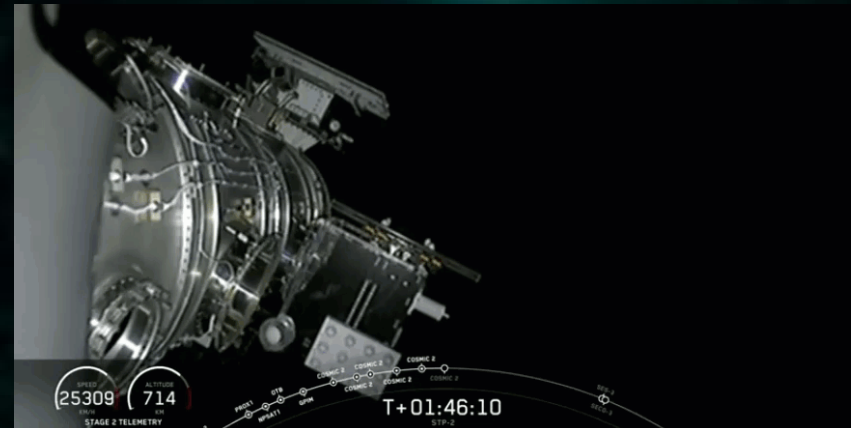


# COSMIC-2/FORMOSAT-7 Mission

- 6 Satellite constellation around the equator (24 degree inclination orbit)
- Each satellite has 3 instruments:
  - TriG GNSS-RO receiver (TGRS) – Primary Instrument
  - Ion Velocity Meter (IVM) – Secondary Instrument
  - RF Beacon – Secondary Instrument
- Mission Design Life: 5 years
- Launch Date: June 25, 2019
- Launch Vehicle: Falcon Heavy (STP-2 mission stack shown in right figure)
- All weather coverage (4,000+ occ/day) with 30 min avg data latency

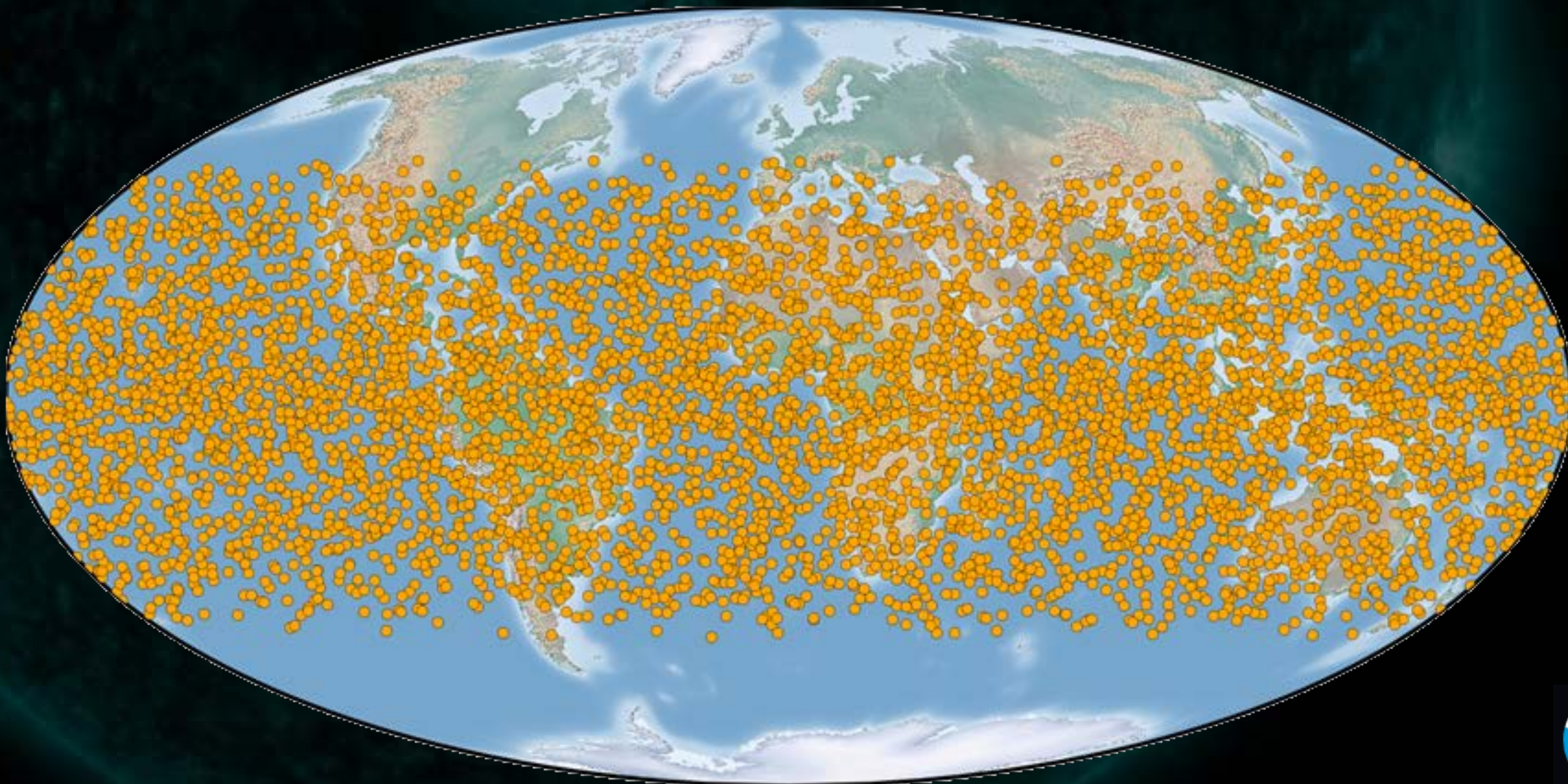


COSMIC-2  
Spacecraft  
in STP-2  
Launch  
Stack



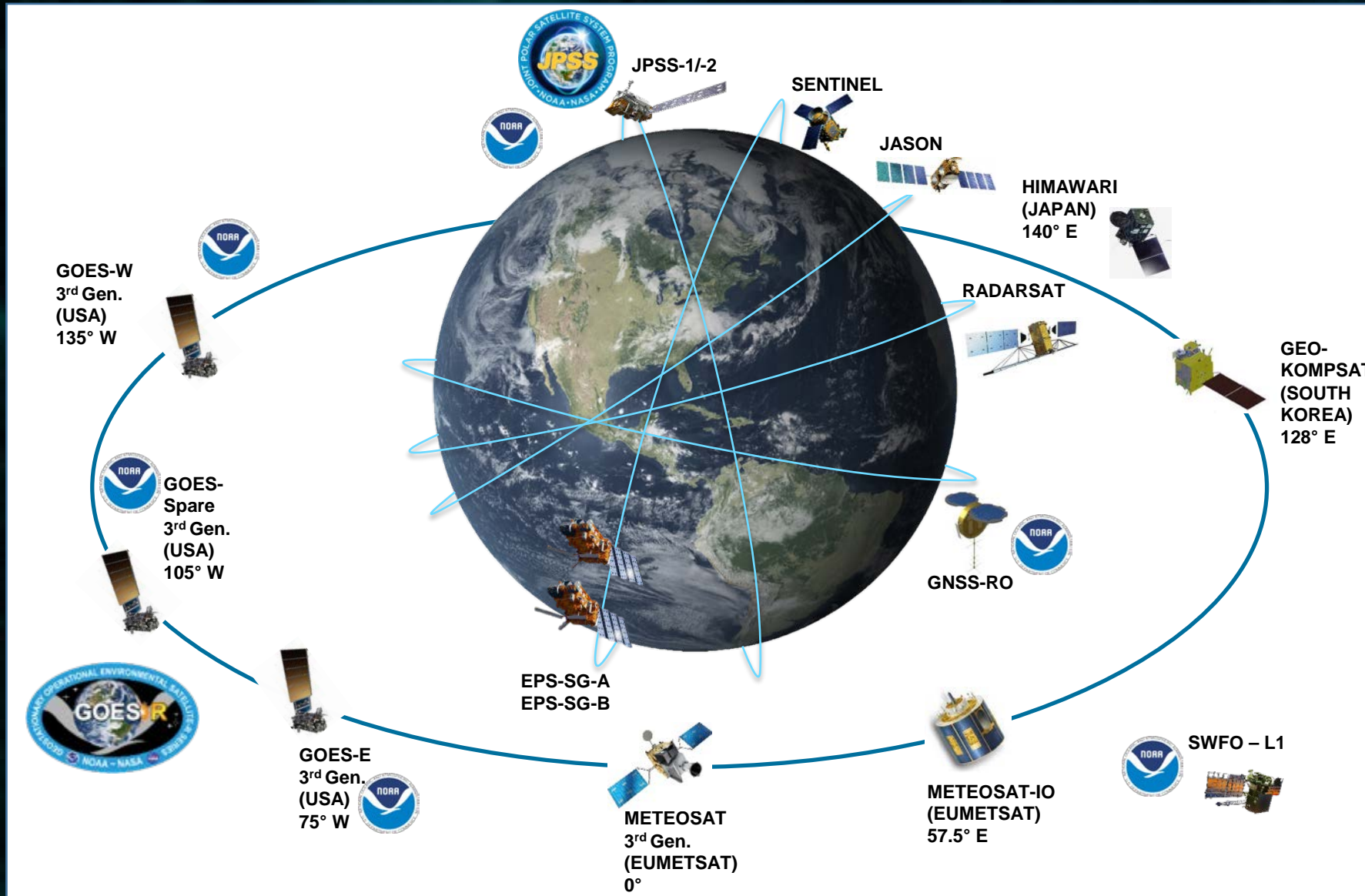


# COSMIC-2 RO Coverage



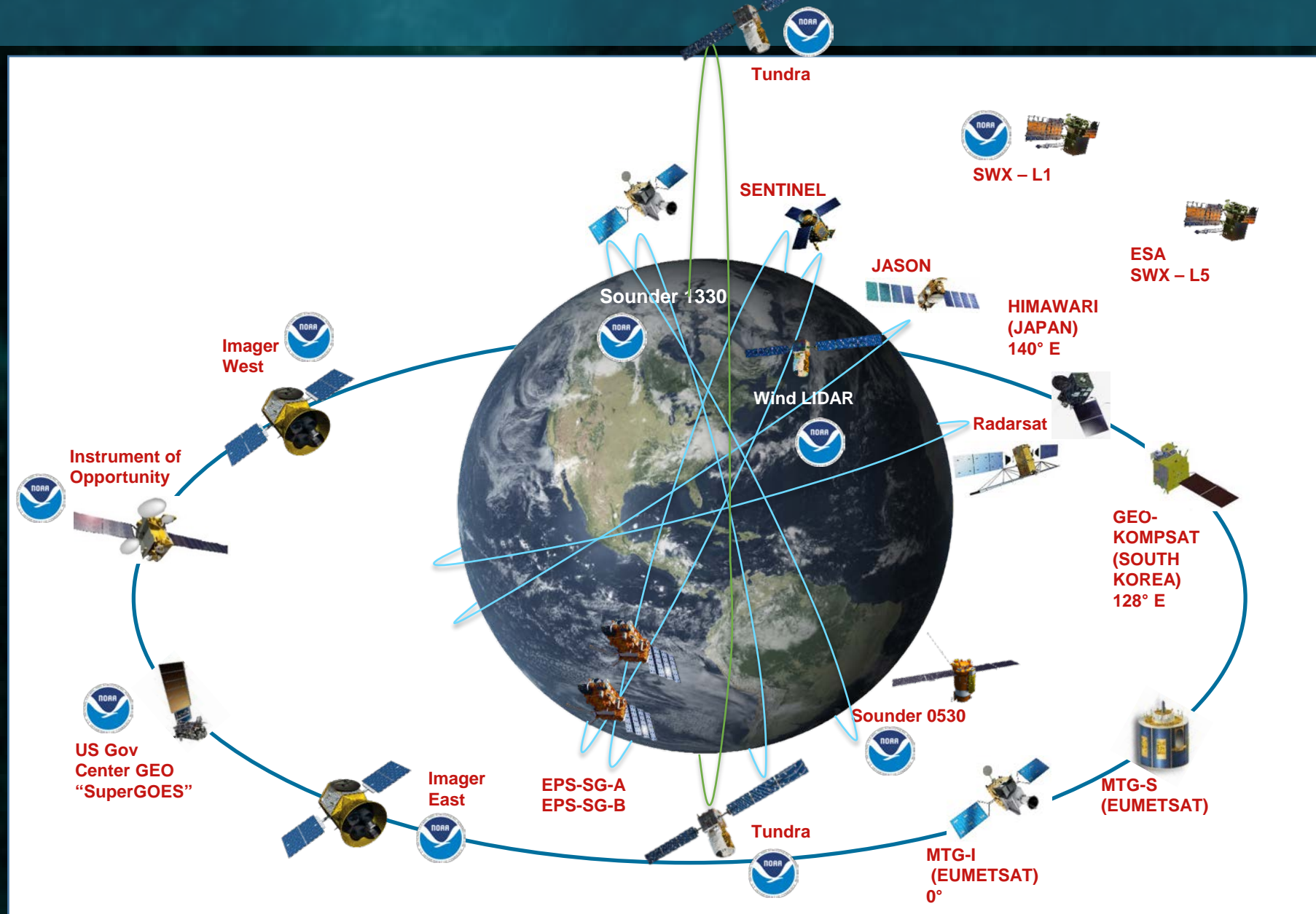


# Near-Term Observational Capability

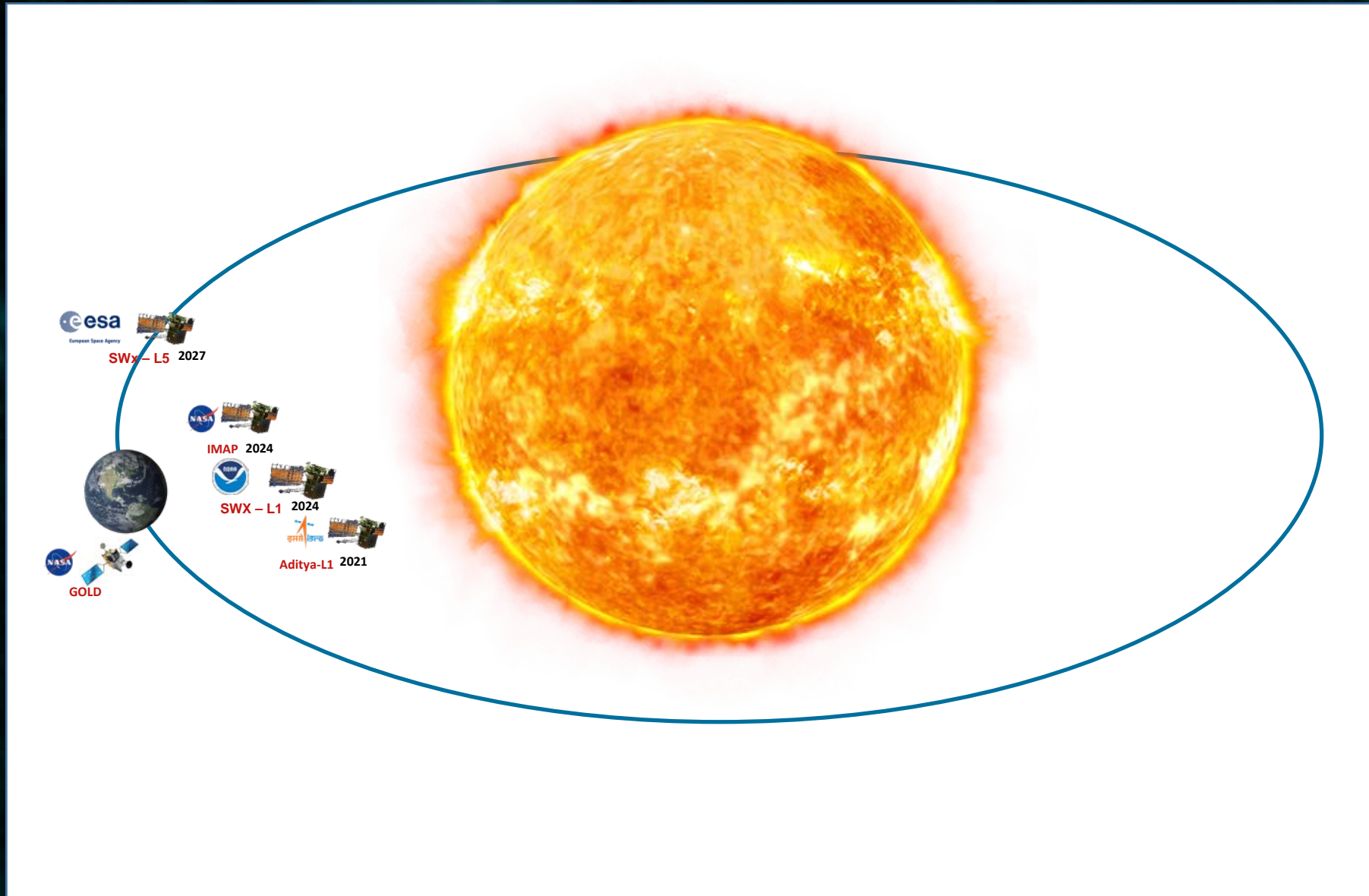




# Evolution of NOAA and Partner Space Architecture

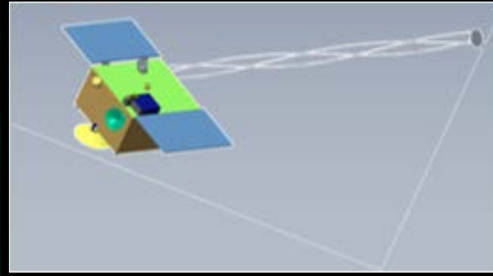


# Evolution of Space Weather Architecture

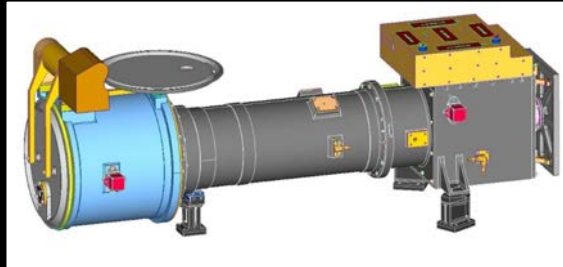


# Starting Point – 2025 Program of Record

3-Axis  
Stabilized ESPA  
Class  
Spacecraft

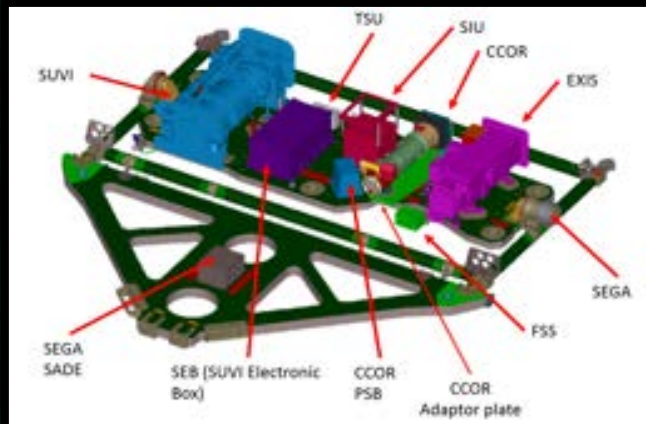


Compact  
Coronagraph  
(CCOR)



GOES-U Solar Pointing Platform (SPP)

CCOR +  
SUVI +  
EXIS



2025 NOAA Space Weather  
Observing Program of Record  
Starting point for Infrastructure Workshop

SWFO – L1 platform  
GOES – U  
COSMIC-2  
GOLD  
Metop – C, SG A1, SG B1  
*ESA – L5 (2027)*



What's next for 2030 and beyond?





# Space Weather Operations and Research Infrastructure Workshop

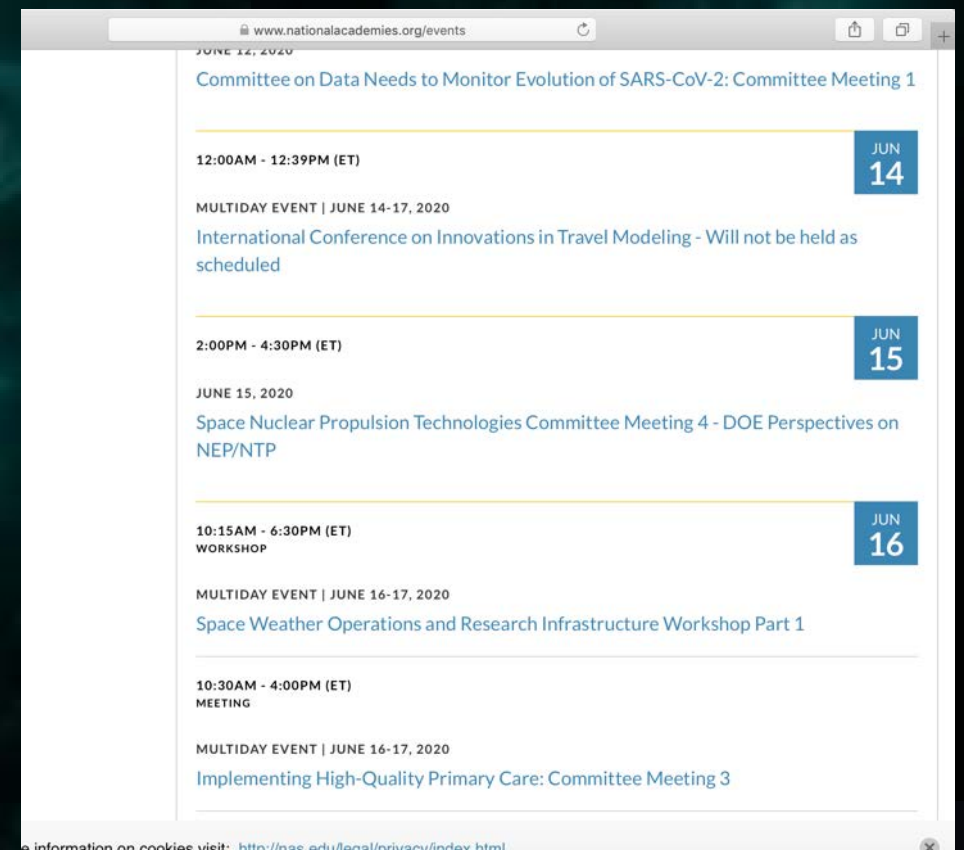
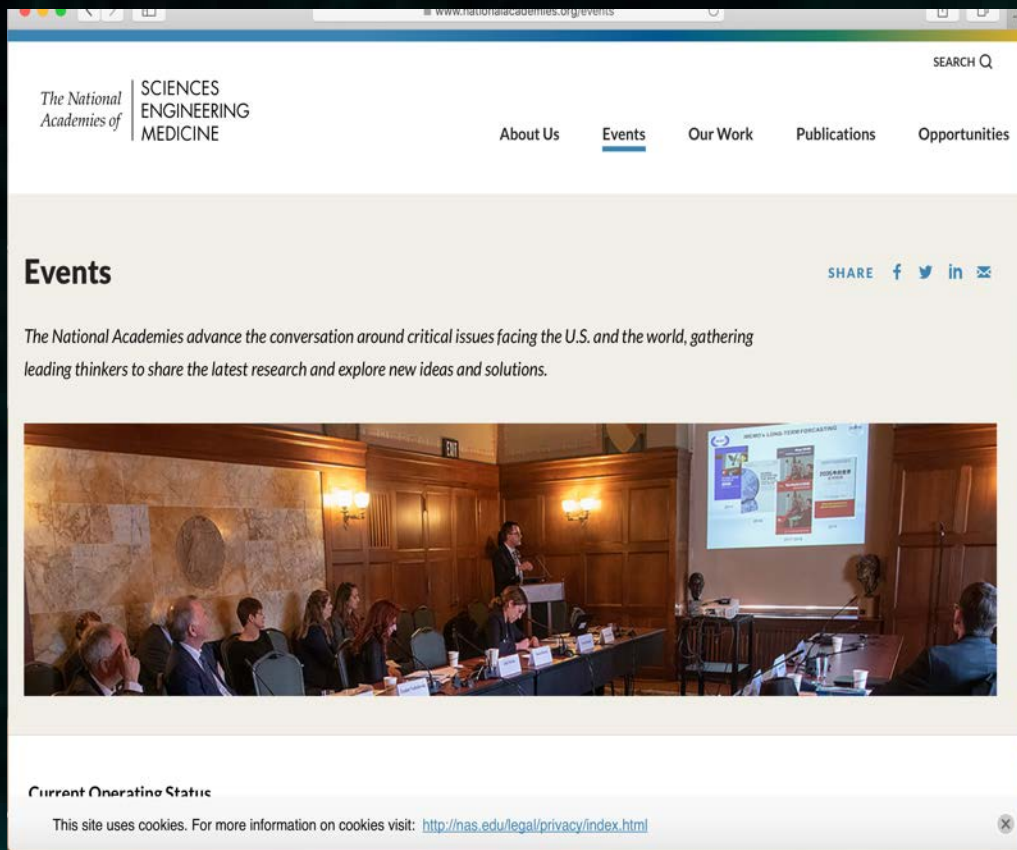
- National Academies via an appointed ad hoc committee will conduct a workshop that will consider options for continuity and future enhancements of the space weather operational infrastructure. Objectives include:
  - Review current and planned U.S. and international space weather-related observational capabilities;
  - Discuss space weather observational needs;
  - Identify programmatic and technological options to ensure continuity of the baseline, the Program of Record (POR), giving particular attention to options to extend the Space Weather Follow On (SWFO) program; and
  - Consider options for technology, instrument, and mission development to support in situ and remote sensing space weather observations from either ground- or space-based vantage points, the latter including L-1, L-5, L-4, L2, 1Au coverage, sub-L1, Tundra, GEO, GEOtransfer, and LEO among others.

# Space Weather Operations and Research Infrastructure Workshop - Status

- The NASEM has approved the Space Weather Operations and Research Future Infrastructure Workshop
- The NASEM has selected an ad hoc organizing committee
- Meetings of the organizing committee have developed the agenda and space weather experts' participation
- The initial workshop is to be conducted in two stages:
  - Stage 1 – 16-17 June, 2020 (virtual)
  - Stage 2 – 10-11 September (in-person and/or virtual)
- A follow on workshop (NASA and NSF supported) will be held to address out-of-scope issues encountered in the first workshop

# Space Weather Operations and Research Infrastructure Workshop – NAS Posted Link

<https://www.nationalacademies.org/events>





# THANK YOU!

For more information visit: [www.nesdis.noaa.gov](http://www.nesdis.noaa.gov)

## CONNECT WITH US!



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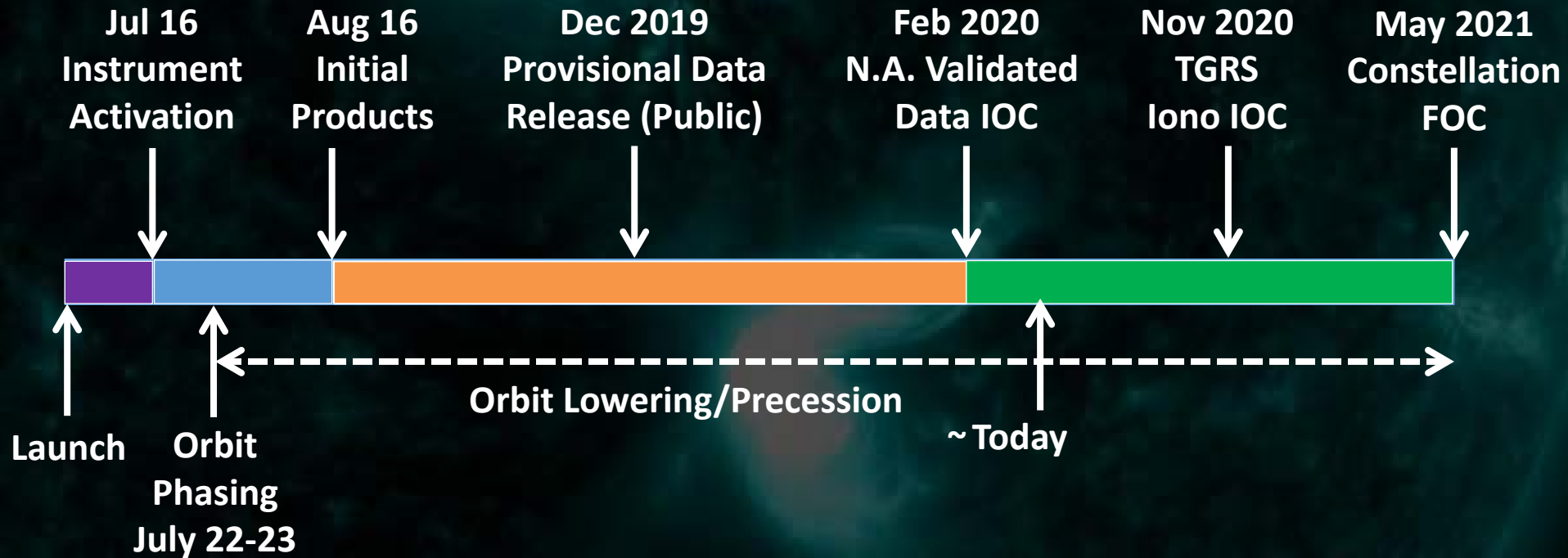
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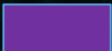





NOAASATELLITES



# COSMIC-2 Data Release Timeline



-  Launch and early orbit operations
-  Checkout and commissioning
-  Weather cal/val
-  Weather operations

IOC = Initial Operational Capability  
FOC = Full Operational Capability  
N.A. = Neutral atmosphere  
Iono = Ionosphere