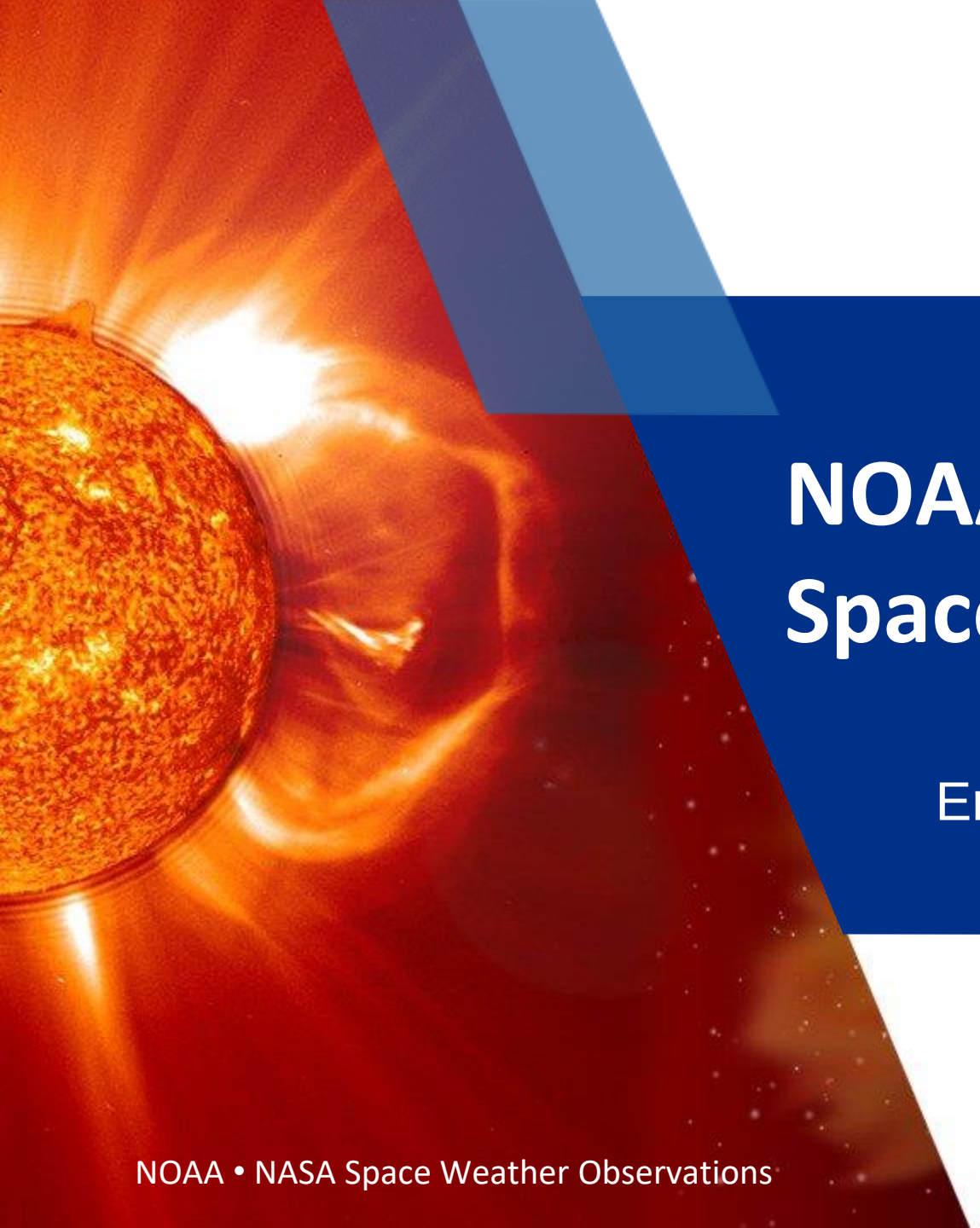


NOAA's Space-Based Space Weather Observations

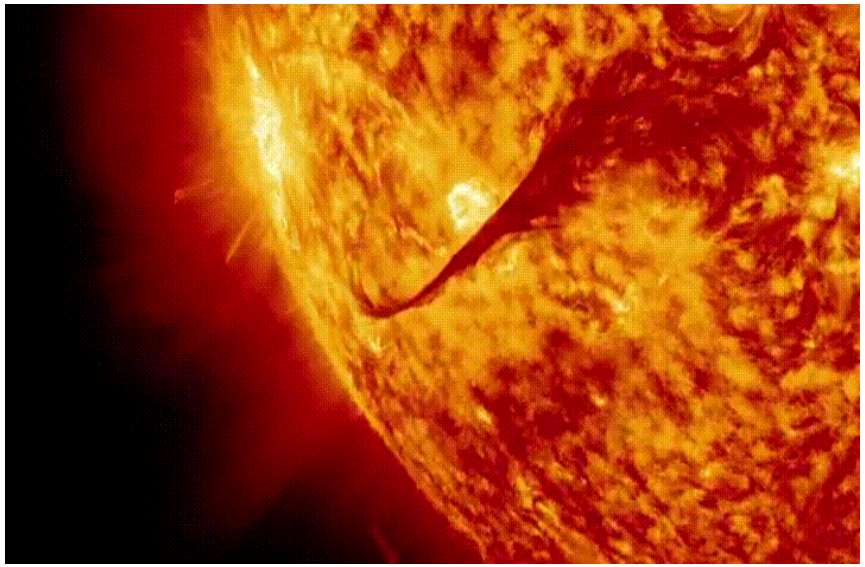
Erin Lynch and Nai-Yu Wang

NOAA / NESDIS / SWO

NOAA's Space Weather Role

NOAA's responsibilities include:

- provide operational space weather monitoring, forecasting, and long-term data archiving and access for civil applications,
- maintain ground-based and space-based assets to provide observations needed for space weather forecasting, prediction, and warnings,
- provide research to support operational responsibilities, and
- develop requirements for space weather forecasting technologies and science.



NESDIS Strives to Provide Integrated, Digital Understanding of Earth

1. Advance terrestrial observational leadership in geostationary and extended orbits

2. Advance space weather observational leadership in all applicable orbits to meet mission needs

3. Evolve LEO architecture to enterprise system of systems that exploits and deploys new observational capabilities

4. Develop agile, scalable ground capability to improve efficiency of service deliverables and ingest of data from all sources

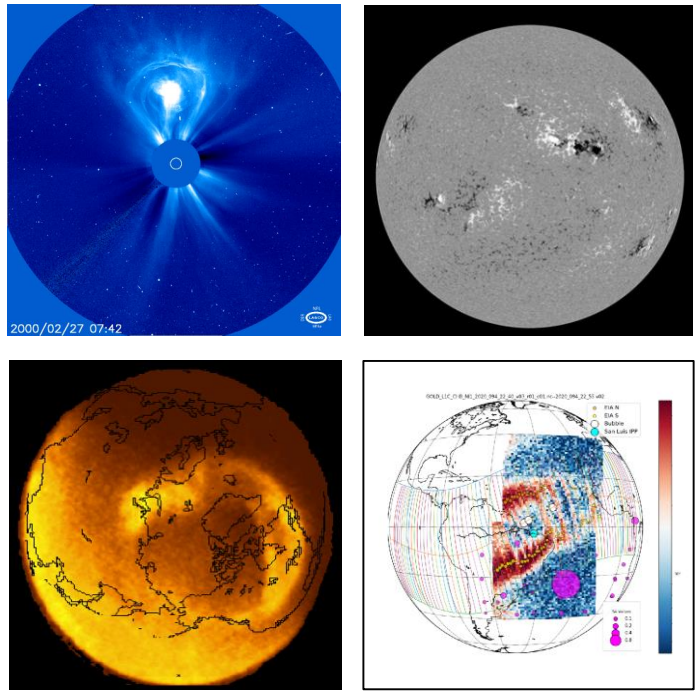
5. Provide consistent ongoing enterprise-wide user engagement to ensure timely response to user needs

6. Deliver the best value integrated suite of products and services responsive to user needs.

NOAA's Office of Space Weather Observations (SWO)

SWO's core responsibilities include:

- Provide data for operational space weather monitoring, forecasting, and long-term data archiving and access for civil applications
- Maintain space-based assets to provide observations needed for space weather forecasting, prediction, and warnings
- Develop and augment space-based capabilities to improve data for forecasting of space weather events and their impacts

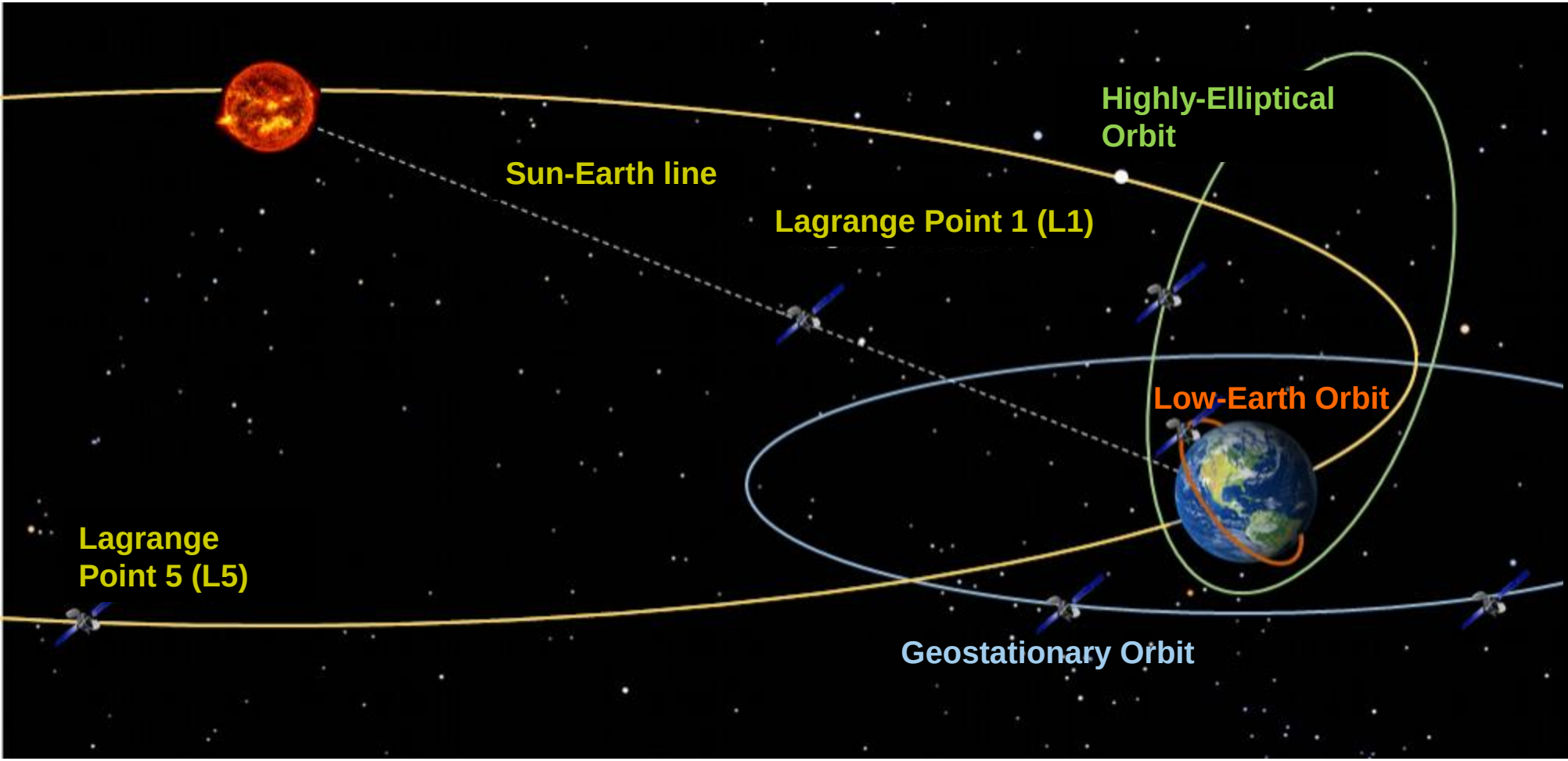


Clockwise from top left:

- Coronal imagery (LASCO)
- Magnetograph imagery (HMI)
- Thermospheric imagery (GOLD)
- Aurora (POLAR)

Data Continuity and Potential New Observations

We collect space weather data to know what is happening and to predict the effects and issue warnings and alerts.



Measurements are collected in many locations.

From L5 we get early info about solar activity soon to face Earth.

From L1 we get early warning of what is coming towards us.

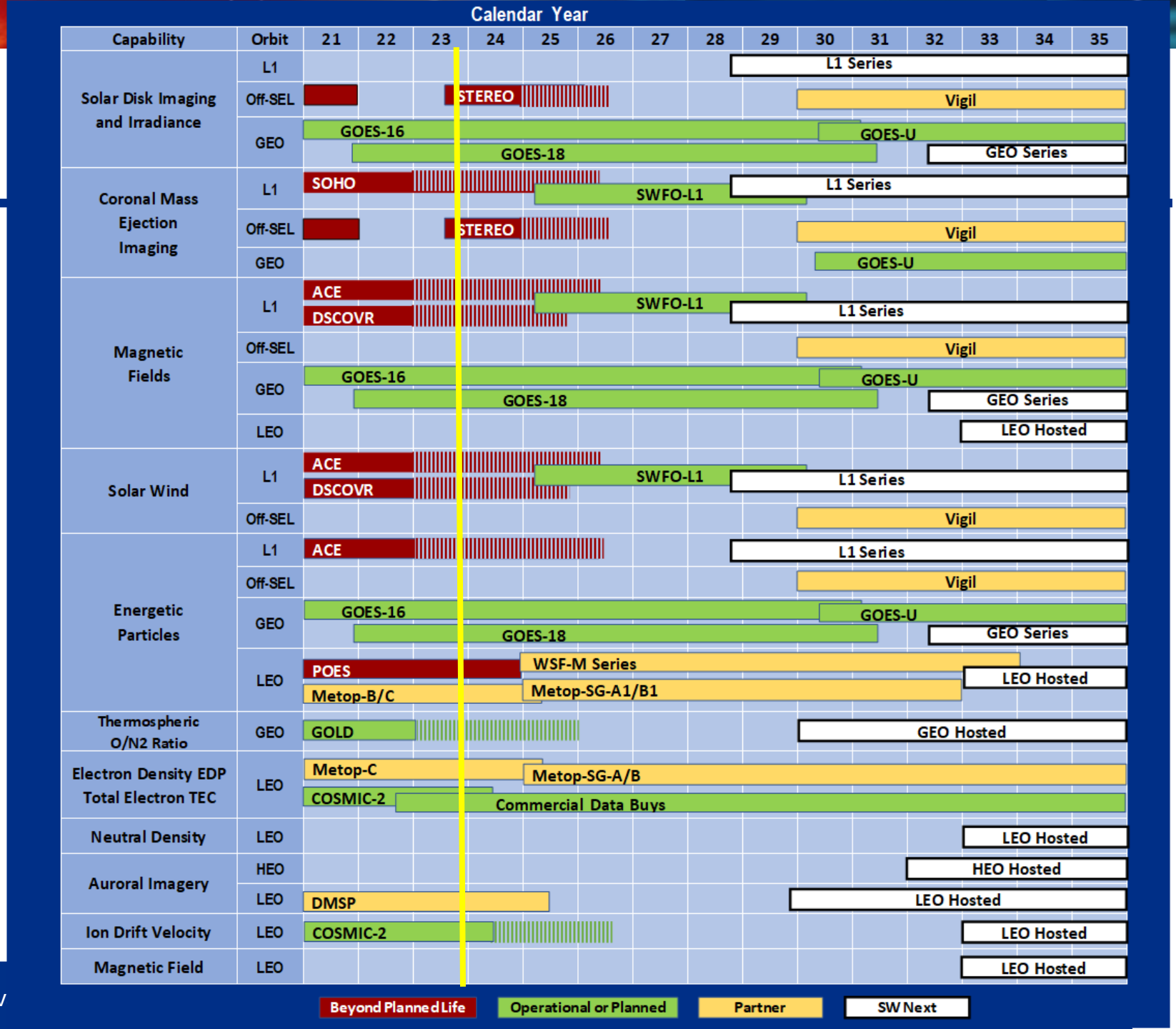
From Earth orbit we measure the local space weather effects, radiation, particles, etc.

Our current satellite constellation is fragile

- DSCOVR, SOHO, ACE are operating beyond predicted end of life.
- Developing follow on systems (SWFO L1, SW Next L1) before current platforms cease to provide useable data.

NOAA's space-based observations will provide critical data continuity

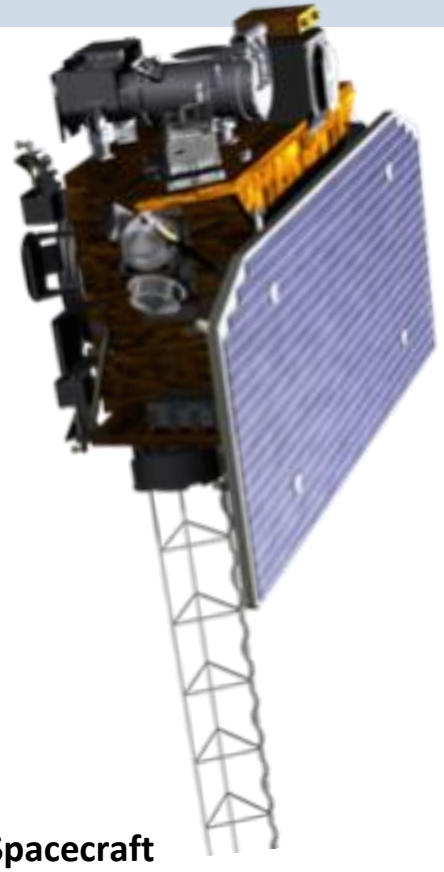
Plans are notional and subject to appropriations.



Space Weather Follow On (SWFO) program

SWFO sustains NOAA's foundational set of space-based space weather observations and measurements to ensure continuity of critical data.

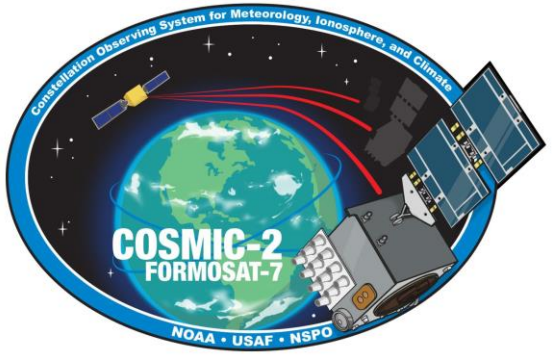
- **Development underway for:**
  - SWFO-L1 Observatory
  - Instruments (CCORs, MAG, SWiPS, STIS)
  - Ground Segment (Command & Control, SWFO Antenna Network, and Product Generation and Distribution)
- **Established agreements** with NASA, NRL, and European Space Agency (L1 & L5 cooperation)
- **Completed SWFO Program & Flight Project Critical Design Reviews** (May 2022)
- **On track for launches** in 2024 (GOES-U Mission) and 2025 (SWFO L1 Mission)



SWFO-L1 Spacecraft
Image Credit: Ball Aerospace

Space-Based Monitoring at NESDIS

- SWFO – L1
  - Solar Wind, Magnetic Field, and Particle Flux
  - Sun-Earth Line (SEL) Coronagraph
- GOES–R series
  - Magnetic Field and Energetic Particles
  - SEL Solar UV and X-ray Irradiance Imaging
  - SEL Coronagraph on GOES-U
- COSMIC-2 and Commercial RO
- EUMETSAT MetOp-C, -SG
  - Energetic Particles
  - Ionospheric Products via Radio Occultation
- ESA – Vigil at L5
  - Off SEL Solar Imagery; incl. Coronagraph
  - Magnetic Field and Solar Wind



EUMETSAT

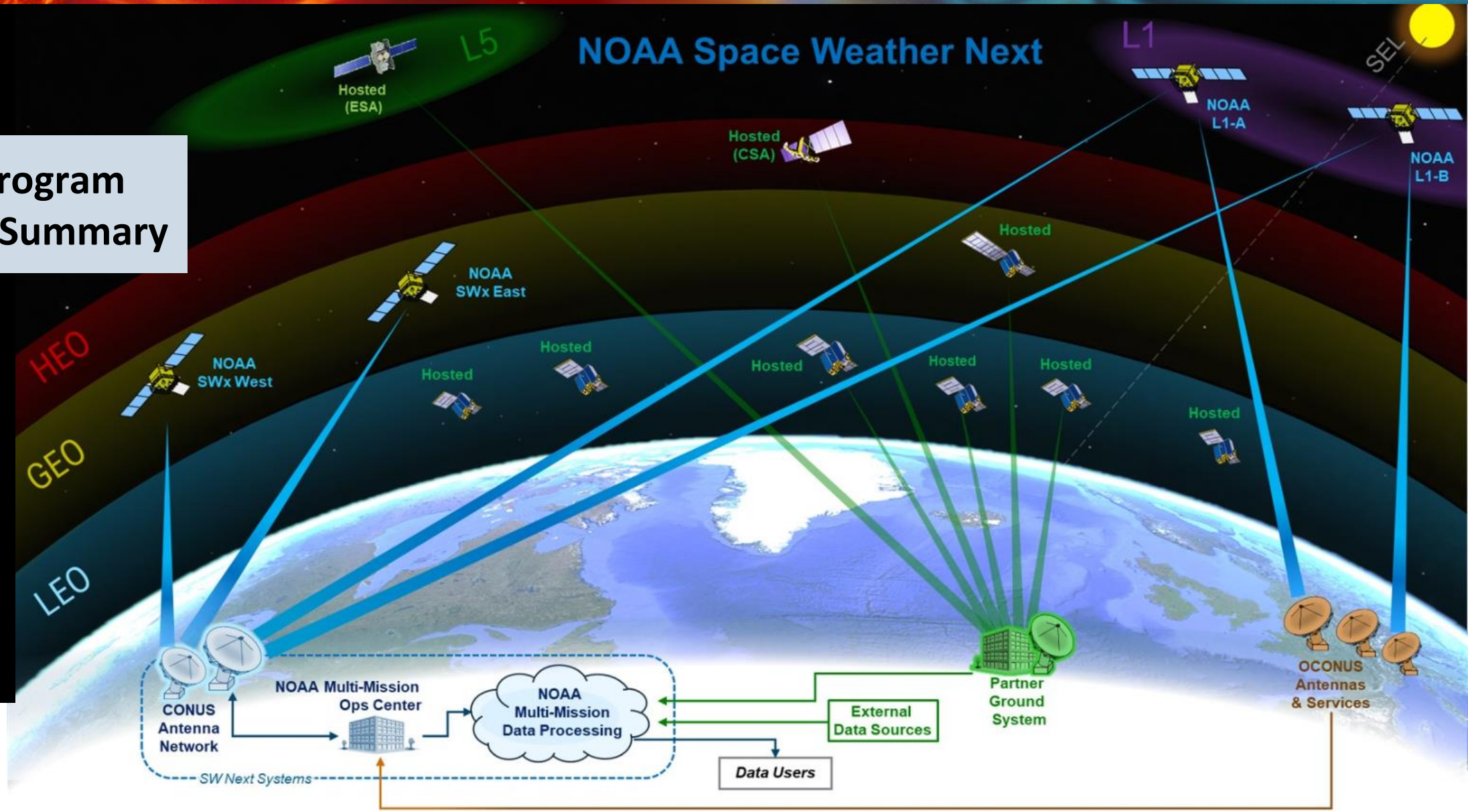
SW Next Observations

In order to provide continuity for current space weather forecast and monitoring capabilities, as well as enhancements, the SW Next program includes the following observation objectives:

Category	Data Products
Solar Observations	Coronal White Light Imagery (SEL and Off-SEL)
	Photospheric Magnetograph Imagery (SEL and Off-SEL)
	Solar EUV Imagery (SEL)
	Solar X-ray Irradiance (SEL)
	Solar EUV Irradiance (SEL)
Heliospheric Observations	Heliospheric Imagery (SEL and Off-SEL)
	Solar Wind Density, Velocity, Temperature (SEL and Off-SEL)
	Solar Wind Low Energy Proton Flux (SEL and Off-SEL)
	Magnetic Field (SEL and Off-SEL)
	Solar Energetic Particle Flux (SEL and Off-SEL)

Category	Data Products
Magnetospheric Observations	Magnetic Field (GEO)
	Energetic Particle Flux (GEO)
Ionospheric and Thermospheric Observations	Electron Density Profile
	Total Electron Content
	Ionospheric Irregularities
	Ion Drift Velocity
	Auroral Imagery
	Energetic Particle Differential Flux
	Upper Thermospheric Density
	Thermospheric O/N2 Ratio
	Thermospheric Neutral Winds

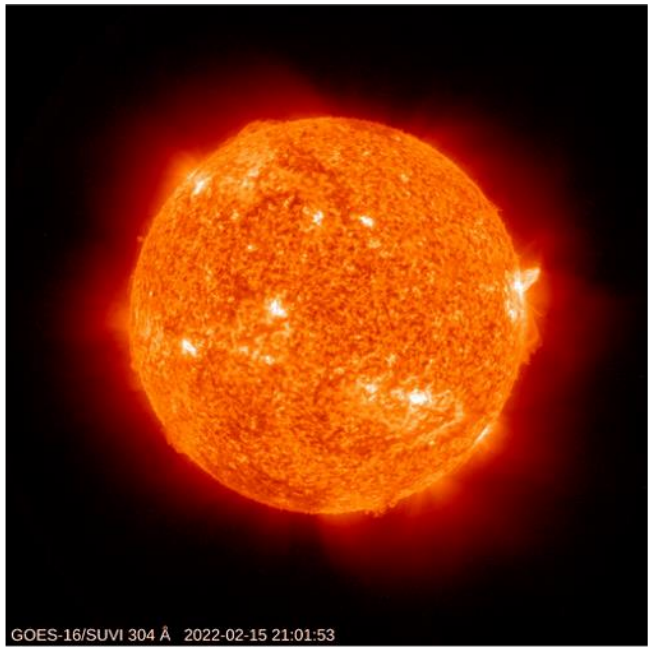
SW Next Program Architecture Summary



Space Weather Next (SW Next) program

SW Next will **maintain and extend** space weather observations from a range of different observing points, selected to most efficiently provide comprehensive knowledge of the Sun and the near-Earth space environment.

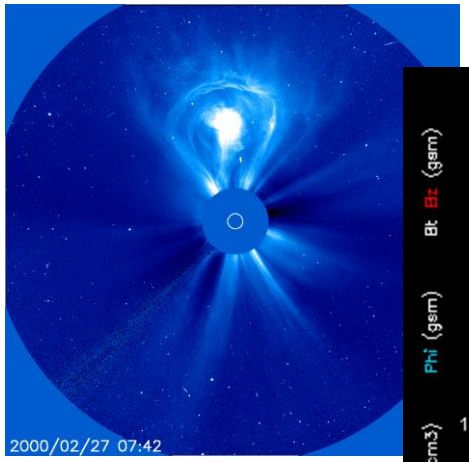
- **Planning for continuity of observations**:
  - L1 and L5 orbits
  - Geostationary and Low-Earth orbit
  - Ground support networks
- **Formulation underway** for Program, L1 Series Project, and L5 Project
- **Pre-Formulation started** for GEO Series Project
- **Engaging stakeholders** via user outreach, partnerships, and market research

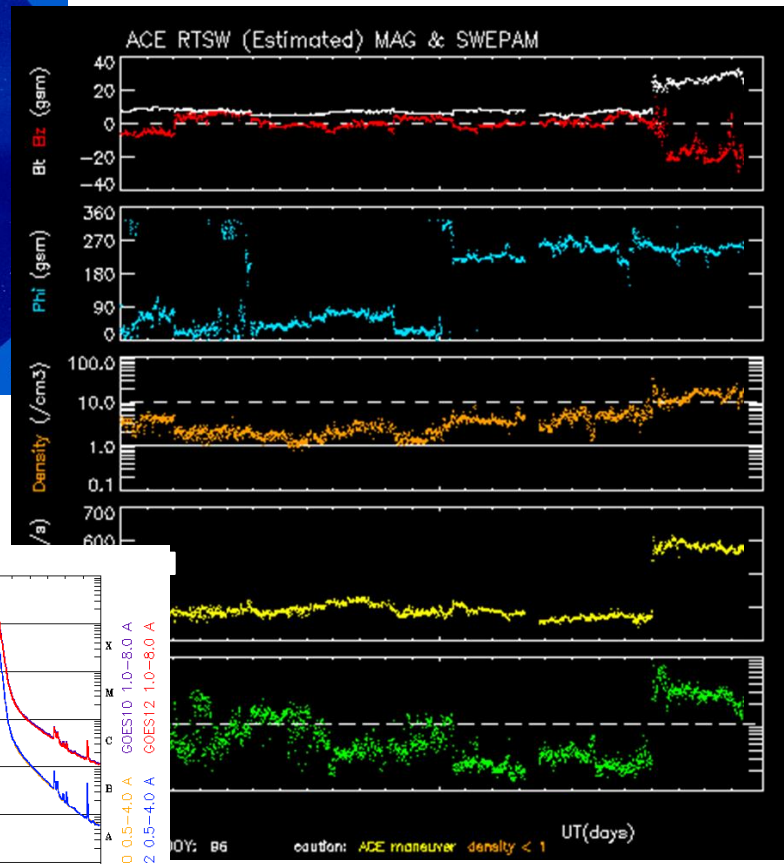


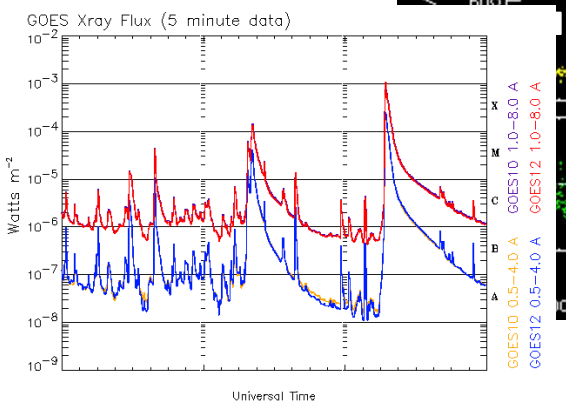
SW Next L1 Series

Primary observation objectives:

- Coronal White Light Images for detection of CMEs
  - Observe CME parameters, shape, density, velocity
  - Produce CME characteristics for input into operational heliospheric propagation code
- In situ solar wind measurements
  - Measure solar wind magnetic field, thermal plasma, and energetic particles
  - Detection of geoeffective solar wind features
  - Driver for geospace and ionosphere models
- Solar X-ray Irradiance for flare detection



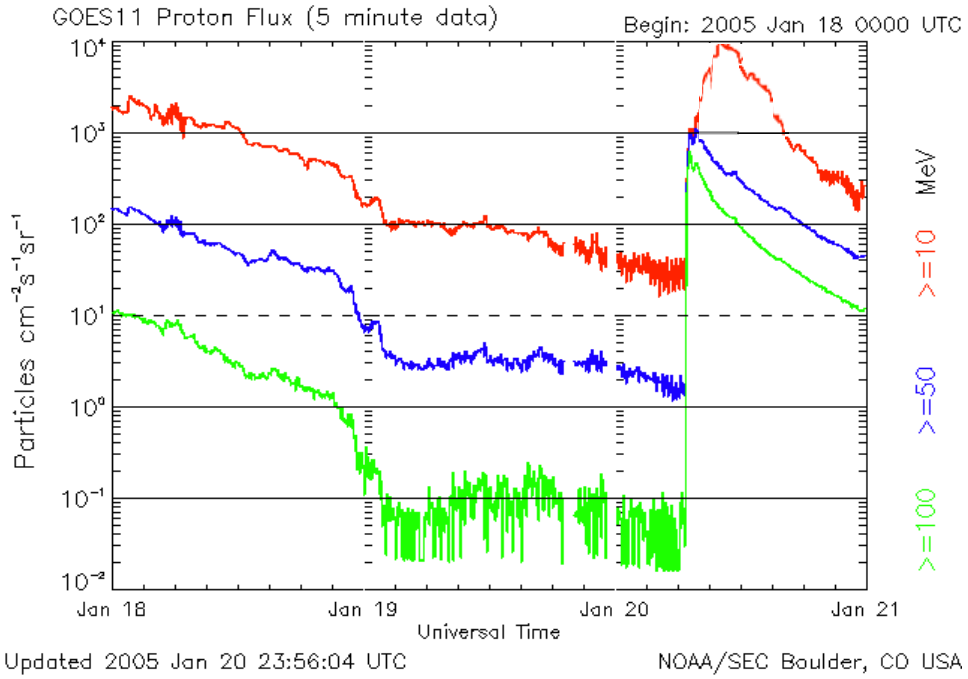




SW Next GEO Series

Primary observation objectives:

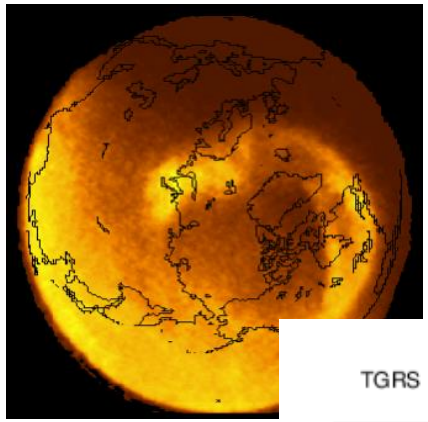
- In situ measurements of energetic particles and magnetic fields
  - Characterize the near earth radiation environment and potential hazards to spacecraft, aircraft, and human life.
- Solar EUV measurements
  - Detection of solar features
  - Drivers of ionospheric models

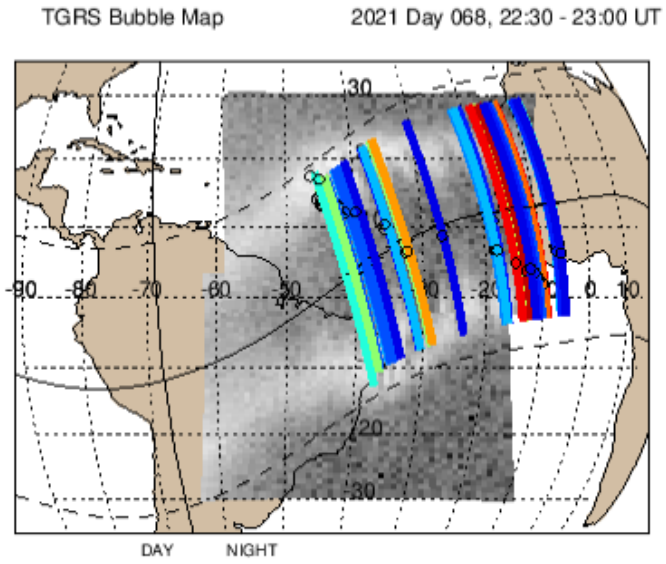


SW Next LEO Instruments

Observation objectives:

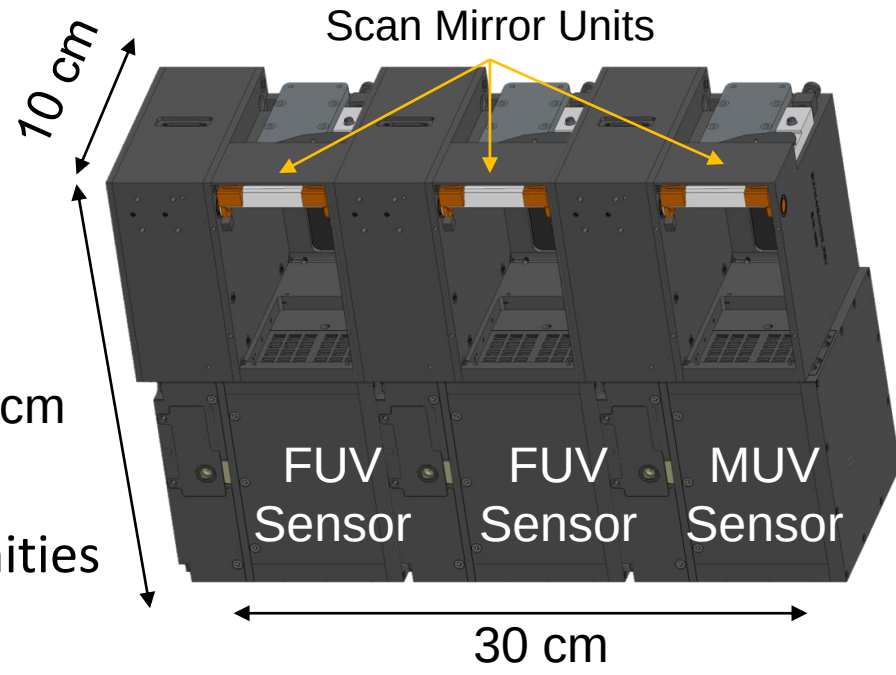
Category	Data Products
Ionospheric and Thermospheric Observations	Electron Density Profiles
	Total Electron Content
	Ionospheric Irregularities
	Ion Drift Velocity
	Auroral Imagery
	Energetic Particle Differential Flux
	Upper Thermospheric Density
	Thermospheric O/N2 Ratio
	Thermospheric Neutral Winds





TRITON Instrument Development

- **TRITON Instrument Development**: NOAA NESDIS is funding the Naval Research Laboratory (PI: Bruce Fritz, NESDIS lead: Nai-Yu Wang) to develop the Tiny Remote-sensing Instrument for Thermospheric Oxygen and Nitrogen (TRITON)
- TRITON is designed to determine O and N_2 density profiles in the daytime thermosphere with ultraviolet remote sensing from a CubeSat-sized platform
- 6U core consists of 3 sensor/mirror pairs:
  - (1) O sensor + (1) SUVM (UV scanning mirror)
  - (1) N_2 sensor + (1) SUVM
  - (1) O^+ sensor + (1) SUVM
- Status: Technology readiness level (TRL) 4
- Next steps: Further development to TRL 6 and flight opportunities



On-orbit Neutral Density Derivations

- **Derive on-orbit neutral mass density through SpaceX Starlink Satellite orbit ephemeris**
  Data: NESDIS is funding University of Colorado and SWPC (PI: Eric Sutton, Co-PI: Tzu-Wei Fang, NESDIS lead: Nai-Yu Wang) to explore the potential of using orbit ephemeris to derive neutral density from a large number of Starlink satellites and provide these measurements to improve the performance of the operational WAM at SWPC.
- Status: Project kickoff on August 2023 in year 1
  - Year 1: Analyze historical data from Starlink to derive orbit-averaged neutral density from multiple satellites. Examine the quality of the derived neutral density and the orbits of the satellites that might be suitable for the task. Determine how many satellites might be needed for real-time operations (details see Eric Sutton's presentation in Advances in Neutral Density Research Session).
  - Year 2: Implement a data-assimilative (DA) system to ingest orbit-averaged density derived from the Starlink Satellite into the operational WAM and provide an assessment of the model performance and forecast skill with the new dataset.

Summary

- SWO will assume responsibility for NOAA space weather observations across all orbital domains and will implement a comprehensive architecture and coordinated program to ensure space weather products are available to meet user requirements through 2050.
- SW Next program will:
  - *Sustain and enhance critical space weather observational capabilities from all applicable orbits*
  - *Improve and expand NOAA's space weather product suite*
  - *Develop partnerships to collect, process, and deliver relevant data to our users*
  - *Ensure continuity of accurate and timely space weather information to user*

SWO User Engagement Contact Information

- SWO User Engagement Coordinators:
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  - Nai-Yu Wang nai-yu.wang@noaa.gov