NOAA Space Weather (SWX) Program: Space Weather Requirements

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Community Meeting on NOAA Satellites

Informing the Future of NOAA Satellite Observations

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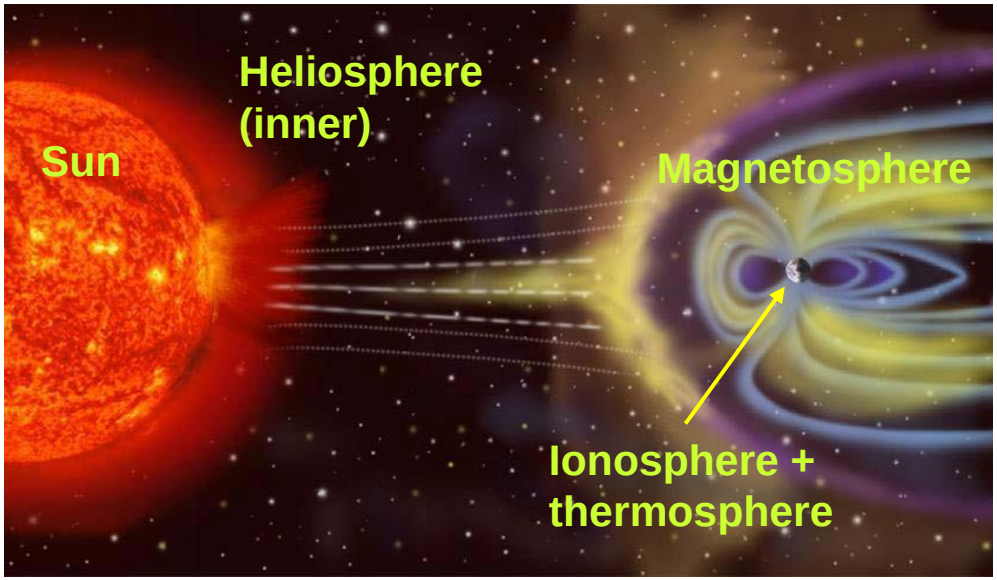
Outline

- The Space Weather Mission Service Area and its domains
- NOAA requirements framework
- Program CONOPS and L1RD
- Science and mission-design trade studies
- Plans for OSEs and OSSEs

Space Weather Mission Service Area

- NOAA classifies weather effects into several Mission Service Areas. Space weather is one of them.



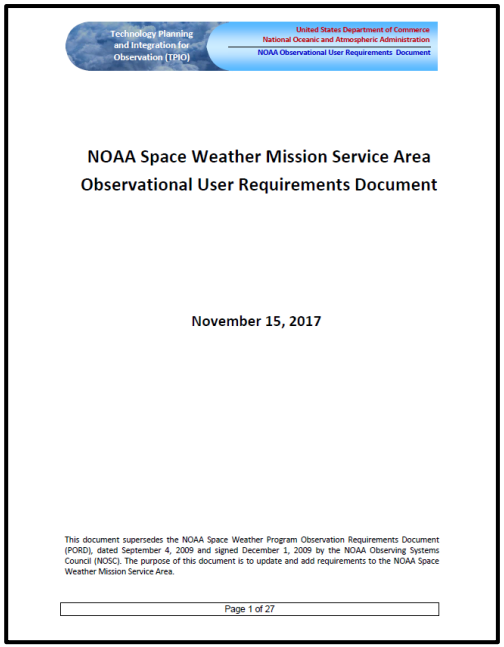
- Space weather effects are further divided by domain:
  - Solar
  - Heliospheric (solar wind-related)
  - Magnetospheric
  - Ionospheric
  - Thermospheric

Often grouped together for conceptual or practical reasons

Closely coupled regions; generally treated as one system

The NOAA COURL

- The basis for all NOAA satellite requirements is the Consolidated Observational User Requirements List (COURL) part of which is the space weather OURD maintained by OSAAP.
- The COURL is the formal basis for the POR 2025, the SPRWG list, and other requirement collections.



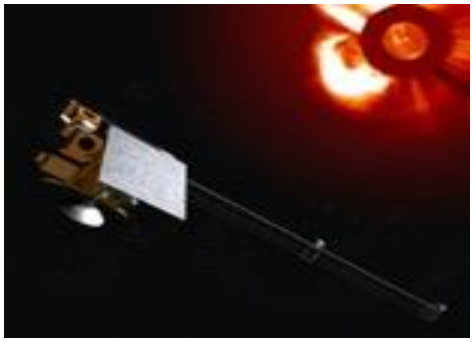
November 2017 OURD

Sample solar-imagery requirements from the OURD.

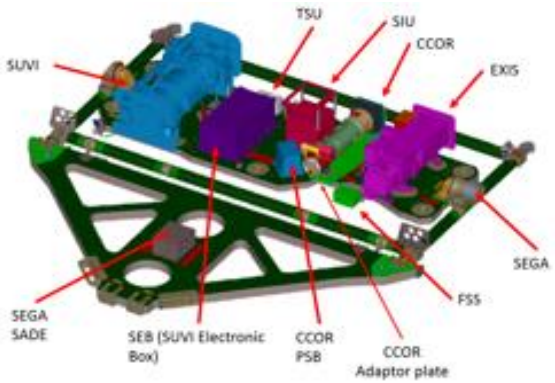
NOAA GCMD Variable	Observation Requirement	Priority	Geographic Coverage Threshold	Vertical Range Threshold	Horizontal/Spatial Resolution Threshold	Measurement Accuracy Threshold	Sampling Interval Threshold	Validation Docs Numbers
Solar Imagery: Heliospheric	Solar Imagery: Heliospheric, L5	1	Heliocentric	15 Solar Radii-1 Astronomical Unit Solar	10 arcmin at inner field of view / 2 deg at outer field of view	10 %	1 hr	26, 27, 28, 36, 45
Solar Imagery: Magnetogram	Solar Imagery: Magnetogram, L1	1	Heliocentric	0 - 1 Rsun	5 arcsec	20 %	3 hr	23, 24
Solar Imagery: Magnetogram	Solar Imagery: Magnetogram, L5	1	Heliocentric	0 - 1 Rsun	5 arcsec	20 %	3 hr	23, 24, 36
Solar Imagery: Multi-Spectral X-Ray/EUV Radiance, Earth-Sun Line	Solar Imagery: Multi-Spectral X-Ray/EUV Radiance, Earth-Sun Line	1	Heliocentric	0-1.3 Rsun	5 arcsec	20%	LTE 2 min	21, 22, 25, 30

The Program of Record 2025

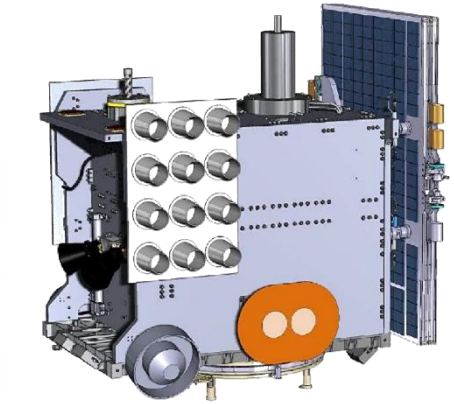
SWFO-L1: CCOR, SWiPS, MAG, STIS, XFM



GOES-U: SUVI, CCOR, EXIS, SEISS, MAG



COSMIC-2: TGRS, IVM, RFB



SpWx Domain	Objective	Orbit	Instrument
Sun	Coronal imagery	GEO, L1	CCOR
Sun	UV imagery	GEO	SUVI
Sun	EUV irradiance	GEO	EXIS
Sun	X-ray irradiance	GEO	EXIS
Solar wind	Plasma	L1	FC, SWiPS
Solar wind	Magnetic field	L1	MAG
Magnetosphere	Particle flux	GEO	SEISS
Magnetosphere	Magnetic field	GEO	MAG
Ionosphere	EDP	LEO	TGRS
Ionosphere	Drift velocity	LEO	IVM
Thermosphere*	O/N2 ratio	GEO	GOLD*

NSOSA and other requirement sources

- In addition to the POR 2025, the requirements development process has relied on several completed studies and ongoing projects.
- The NOAA Satellite Observing System Architecture (NSOSA) was a major internal study for future mission planning documented in its Space Platform Requirements Working Group (SPRWG) final report [2018; also Anthes et al., BAMS 2019].

B16: Auroral imagery	*POR 2025*	*ST (None, values for scoring purposes)*	*OSCAR Threshold*	*COURL Threshold*	*EXP*	*OSCAR Breakthrough*	*ME*	*OSCAR Goal*	*COURL Objective*
Field of View	None	>65 latitude	X	Global	>60 latitude	X	Hemisphere	X	Global
Band Passes Lower Limit Upper Limit	 None None	 400 nm 650 nm	X	X	 110 nm 180 nm	X	 100 nm 190 nm	X	X
Spatial Resolution	None	60 km	X	10 km	50 km	X	10 km	X	1 km
Refresh Rate	None	45 min	X	5 min	20 min	X	1 min	X	1 min
Data Latency	None	60 min	X	15 min	10 min	X	1 min	X	5 min

Auroral imagery requirements [SPRWG final report, 2018]

- In the context of the National Space Weather Strategy and Action Plan, NOAA coordinates its requirements development with those of several other agencies such as NASA, NSF, and DOD. A wide-ranging project is Space Weather Operations, Research and Mitigation (SWORM).
- The final set of requirements determines instrument and orbit selections.

Key Space Weather Observations: SPRWG

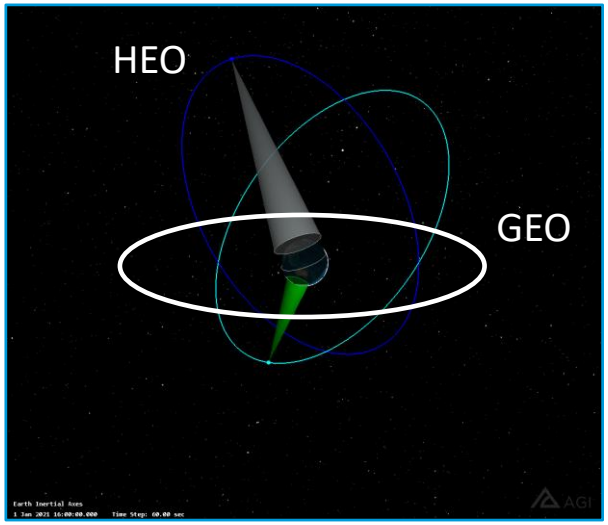
Program of Record 2025	Coronagraph (L1 or GEO) Solar X-ray Irradiance Solar EUV Imaging Solar EUV Irradiance Solar Wind Plasma and Magnetic Field (L1) Solar Wind Suprathermal Particles (L1) Magnetospheric Energetic Particles (GEO) Magnetospheric Magnetic Field (GEO) Ionospheric Radio Occultation and Ion Drift (COSMIC-2 A and B)
Additional observations for consideration in future architecture	Coronagraph (Off Sun-Earth Line) Heliospheric Imager Upper Thermospheric Mass Density Magnetospheric Energetic Particles (non-GEO orbits) Solar Photospheric Magnetograph (Off Sun-Earth Line) Auroral Imaging Neutral Composition - O/N2 Ratio Magnetospheric Magnetic Field (non-GEO orbits) Solar Photospheric Magnetograph (Sun-Earth Line) Solar Wind Plasma (Off Sun-Earth Line) Solar Wind Energetic Particles (L1)

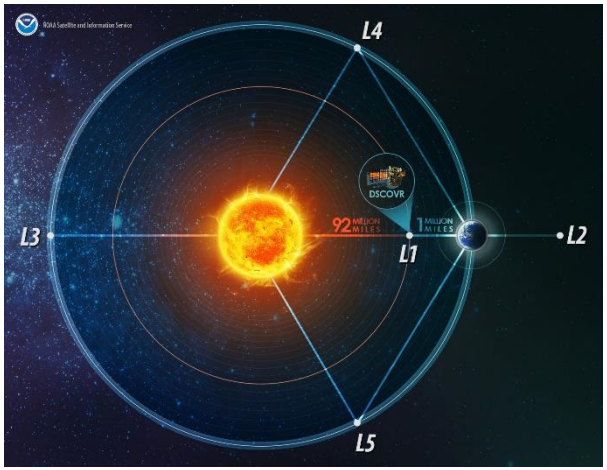
[SPRWG Final Report, 2018; Anthes et al., BAMS 2019]

Plans for a Program CONOPS

- The SWX Program will need a comprehensive observational capability for several orbital regimes.

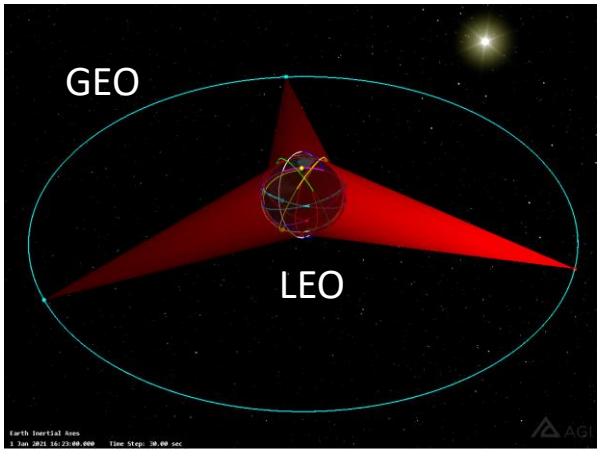
For the magnetosphere, in situ measurements from GEO and HEO can combined with auroral imaging.





Coronal and photospheric imagery from L1 and L5 can be used for stereoscopic analysis. In situ plasma/field data will drive heliospheric models.

Thermospheric and ionospheric objectives will require in situ measurements from LEO as well as imaging capabilities from GEO.



- Balancing requirements with communications, orbit design, hosting, and data buys options is based on feedback from all stakeholders.

The Level 1 Requirements Document

- The formulation working group is developing a preliminary L1RD as part of the preparations for Milestone 1.
- The L1RD reflects the CONOPS considerations mentioned. It contains requirements for operational continuity and observational improvements.

Sample requirement for coronal image intensity

6.1.1. Coronal Image Intensity

[REQ] the Program shall produce a Coronal White Light Intensity observational product from an SEL location in accordance with Table 6.1.

- [SWP_##]

Coronal White Light Intensity	Threshold
Image Center and Orientation	Sun-centered, Solar North-aligned
Field of View (FOV)	2-32 R_{Sun}
Minimum Intensity	$1x10^{-11}$ B_{Sun}
Maximum Intensity	$1x10^{-8}$ B_{Sun}
Spatial Resolution	56 arcsec
Measurement Accuracy	± 10%
Time resolution	15 min
Data Latency	15 min
Location	SEL

Table 6.1. SEL Coronal White Light Intensity requirement.

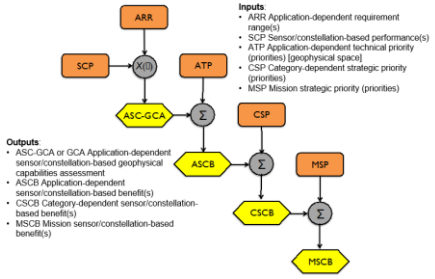
- The requirement structure is often informed by the recent GOES-R and SWFO L1RDs.

Identifying and Parameterizing Requirements

- The Program has developed four initial trade studies to map the trade space for each space weather domain. We will hear from them next.

Study	Domain	Obs. Orbit	Development Team	Presenter
#1, #4	Sun, heliosphere	On/off SEL: L1, sub-L1, L5, drifting	Biesecker, Pizzo, Mulligan	Onsager
#2	Magnetosphere	GEO, HEO	Anand, Onsager, Redmon, Vassiliadis, Zanetti	Redmon
#3	Thermosphere, ionosphere	GEO, HEO, LEO	Azeem, Codrescu, Fuller-Rowell, Makarevich, Onsager, Redmon	Fuller-Rowell

- In addition, team members are working with NESDIS/STAR's ASPEN to provide useful perspectives on orbit allocation.
- The team is working with NASA/GSFC's Mission design Lab (MDL) on the L1 and L5 missions for solar/heliospheric objectives.



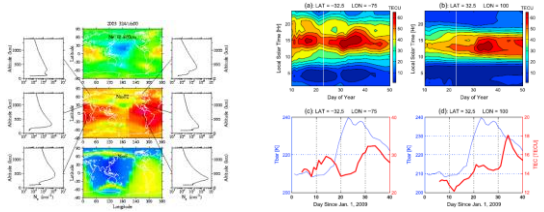
- A second set of trade studies is currently focusing on communications, spacecraft bus design, and launch options.

Plans for OSE/OSSEs

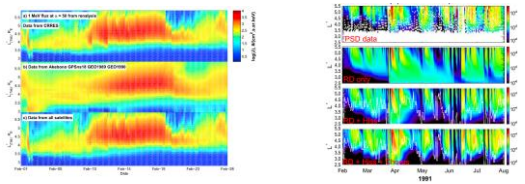
- A number of numerical experiments (OSEs/OSSEs/sensitivity analyses) are considered for providing quantitative support to instrument and orbit selections.
- Two regions where NWP models are sufficiently mature for these experiments are
  1. Thermosphere and ionosphere: Objectives include neutral density, composition, and electron density profiles and derived variables.
  2. Radiation belts (inner magnetosphere): Objectives include particle flux (i+/e-) over several energy ranges, and magnetic field.
- Mission design parameters include: location of sensors, refresh rate, coverage, energy range, etc.
- The goal is to determine, through data denial/addition and other methods, the objectives most relevant to regional space weather nowcasting.

Sample NWP models

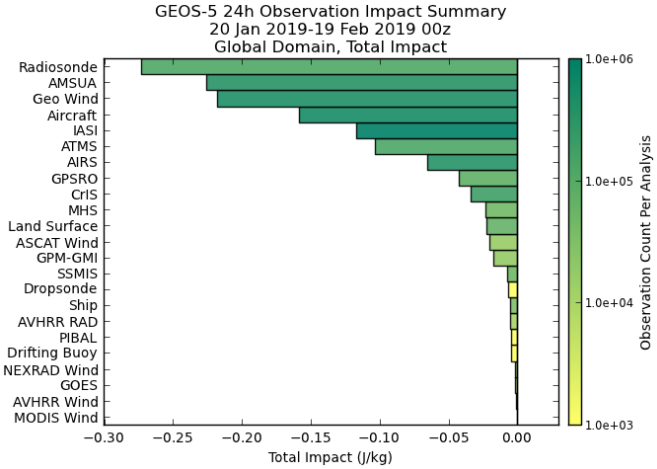
1. Thermosphere and ionosphere



2. Radiation belts



Observation impact summary diagram for tropospheric data assimilation



[NASA/GSFC/GMAO, 2/2019]

Summary

- The Space Weather Program is in the process of developing requirements for all regions from the Sun to the thermosphere.
- The requirements are based on a framework of recent and ongoing NOAA and partner-organization studies such as the NSOSA's SPRWG final report.
- These requirements will be used to determine instrument and orbit selections.
- Several science-focused trade studies have been completed and are now being followed by mission-design studies.
- Quantitative support for the trade studies will rely on numerical experiments such as OSEs and OSSEs.