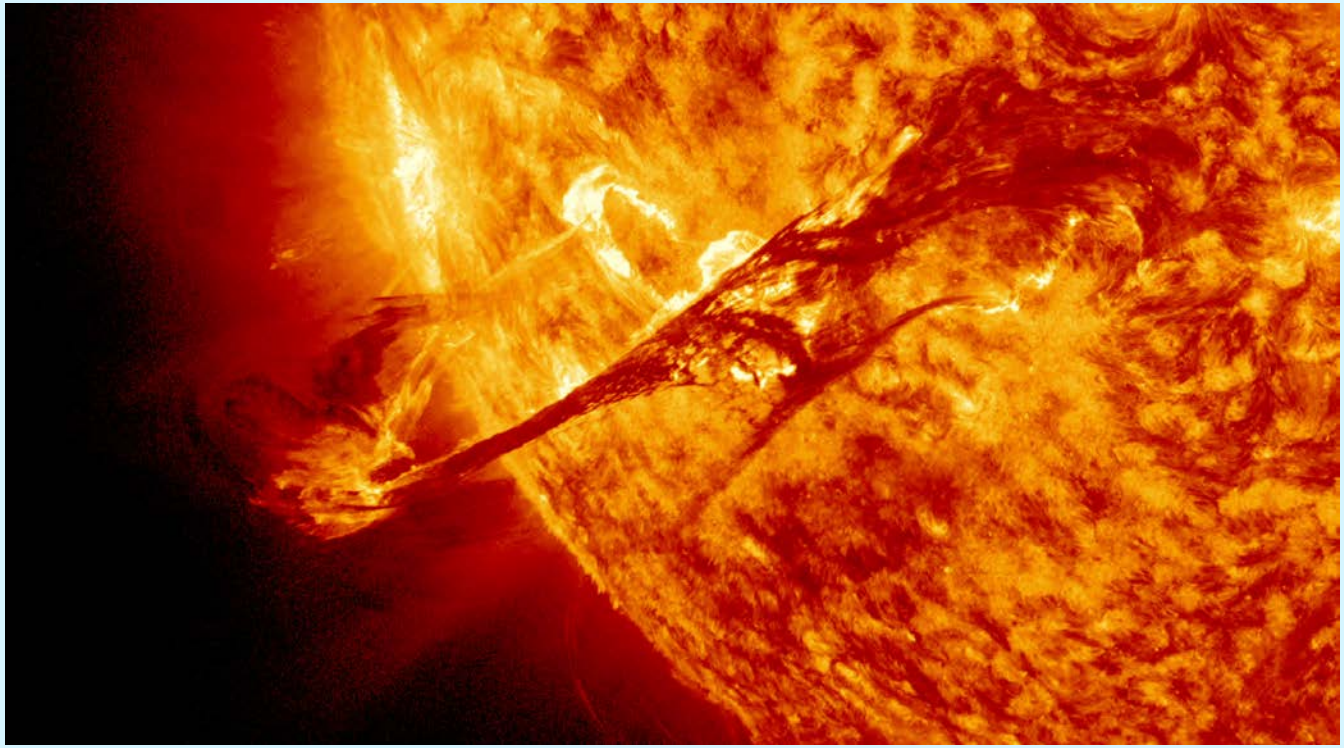
NOAA

NESDIS



The Space Weather Follow On (SWFO) Program to Ensure Continuity of CME and Solar Wind Measurements

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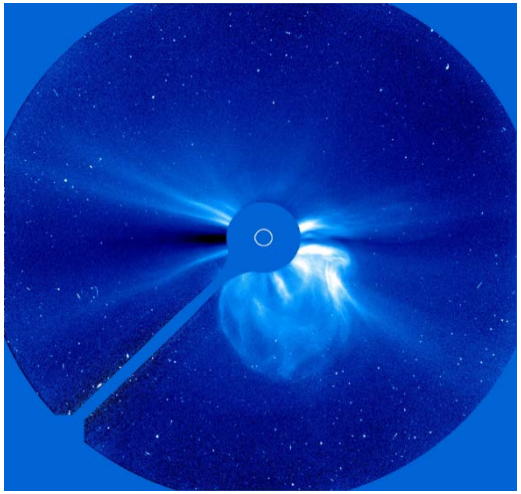
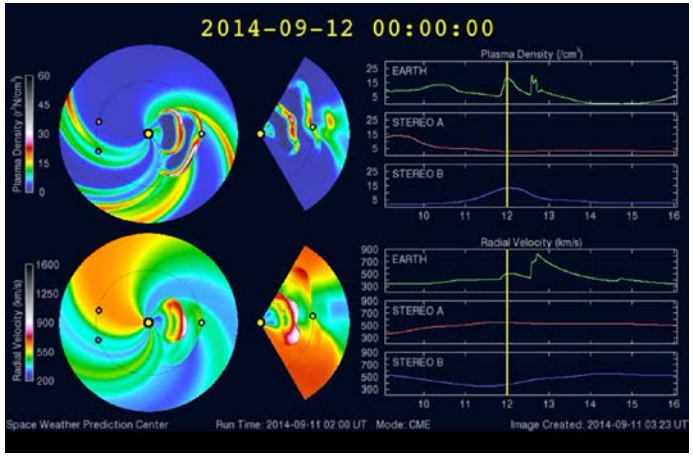
99th AMS Annual Meeting 6–10 January 2019 Phoenix, AZ

In-situ Solar Wind Measurements and CME Imagery are Key for Timely Space Weather Forecasts

NOAA's Space Weather Prediction Center (SWPC) is the nation's official source of Watches, Warnings and Alerts

- Coronal Mass Ejection (CME) Imagery
  - CME imagery (visible-light imagery of the most destructive global events) are used for 1-4-day warnings of geomagnetic storm conditions
  - Currently provided by ESA/NASA Solar and Heliophysics Observatory (SOHO) mission, which launched in 1995
- Upstream Solar Wind Data
  - Solar wind magnetic field and plasma measurement provide 15-60-minute notice for geomagnetic storm conditions
  - Currently provided by NOAA's Deep Space Climate Observatory (DSCOVR) mission, which launched in 2015





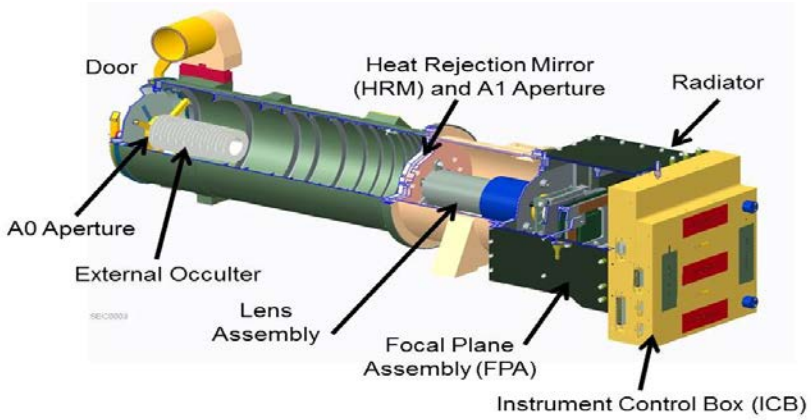
SWPC's Models Require Reliable RTSW Data

SWFO Program Overview

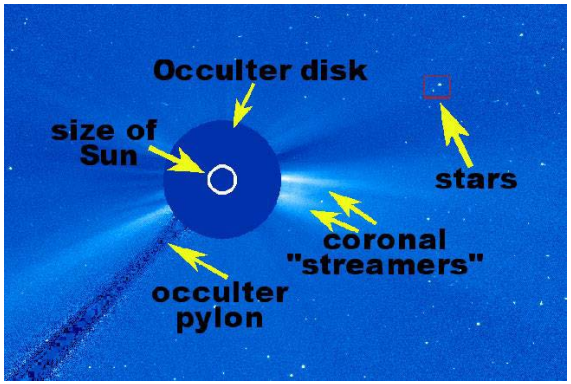
- Sustain a foundational set of space-based observations and measurements (i.e., CME imaging and solar wind measurements)
- Use data from multiple sources (e.g., ESA for L5 observations, U.S. Air Force for energetic particles, and EUMETSAT for ionospheric conditions)
- Ensure continuity of critical data:
  1. Complete the Compact Coronagraph (CCOR) with the Naval Research Laboratory (NRL) as a NOAA reimbursed project
  2. Integrate the first CCOR on the GOES-U spacecraft planned for launch in early 2024
  3. Develop an L1 satellite mission (SWFO-L1) for launch in late 2024:
     - Include a Solar Wind Instrument Suite (SWIS) to measure essential solar wind, and a second CCOR for continuous coronal imagery, and a possible instrument of opportunity
     - Work with NASA to launch the SWFO-L1 mission as a rideshare with NASA's Interstellar Mapping and Acceleration Probe (IMAP)
  4. Establish a robust ground architecture and system together with interagency and international partners to acquire and process data in support of the space weather mission
  5. Archive space weather observations and measurements at the National Centers for Environmental Information (NCEI) to facilitate user access, statistical model development and benchmarking
- Align program with NOAA Satellite Observing System Architecture (NSOSA) calls for sustained Space Weather data and CME imaging capability

A Space Telescope for the Corona: CCOR

Compact **COR**onagraph



Coronagraph Image



CCOR Mission Description

- High heritage from research on CME imagery technology
- Acquire from Naval Research Laboratory (NRL) through interagency agreement
  - Replaces SOHO/LASCO
  - Design traceable to NASA STEREO mission
  - 50% reduction in mass; 2/3 length
- Common design for manifesting either at geostationary orbit or Earth-sun Lagrange point 1

Mission Overview

- CCOR for GOES-U, deliver 2021
- CCOR to be placed on SWFO-L1 spacecraft
- NRL to deliver both in 2021, 2023

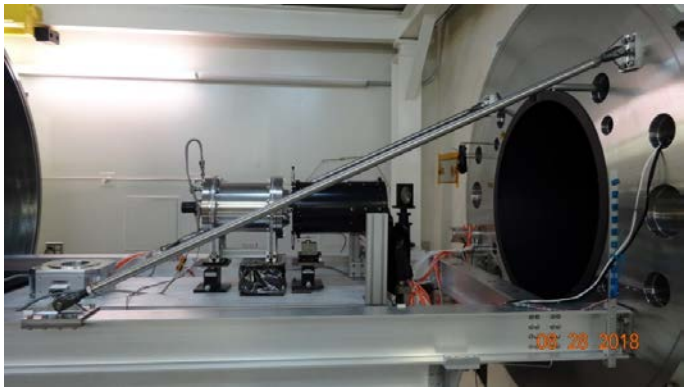
Instrument Requirements

Parameter	Threshold	Goal
Field of View (FOV)	3.7-17 R_{SUN}	3.7-17 R_{SUN}
Pointing Knowledge	25 arcsec	12.5 arcsec
Knowledge of Solar North	1 deg	0.5 deg
Spatial Resolution	50 arcsec	
Photometric Accuracy	10%	
Image Cadence	15 min	5 min
Data Latency	15 min	5 min

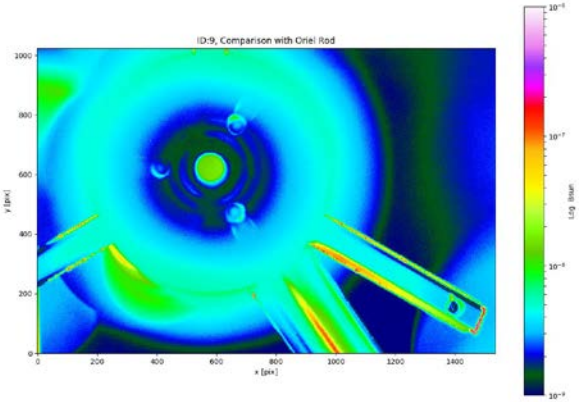
CCOR: Instrument Status

- The CCOR is being developed for NOAA by NRL
- Now in Phase C (final design and fabrication)
  - Successful Preliminary Design Review (PDR) held on September 27-28, 2018
- An optical test bed has been built for development and includes several alternate configurations
- CCOR unit 1 is on track for delivery in March 2021 for integration onto GOES-U

More details on the CCOR instrument:
Poster presentation by Kevin Tewey today from 4:00 to 6:00 PM:
#209. *The NOAA Coronal Mass Ejection Imager for Space Weather Forecasting*



CCOR Optical Testbed

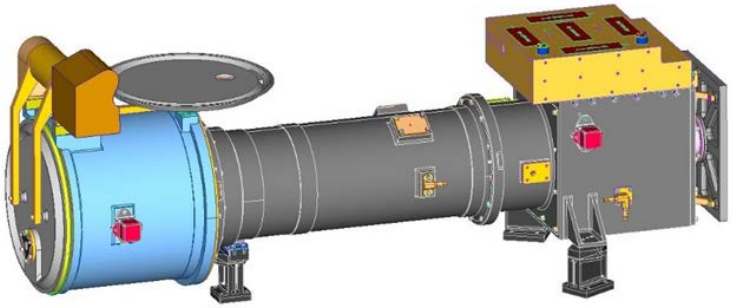


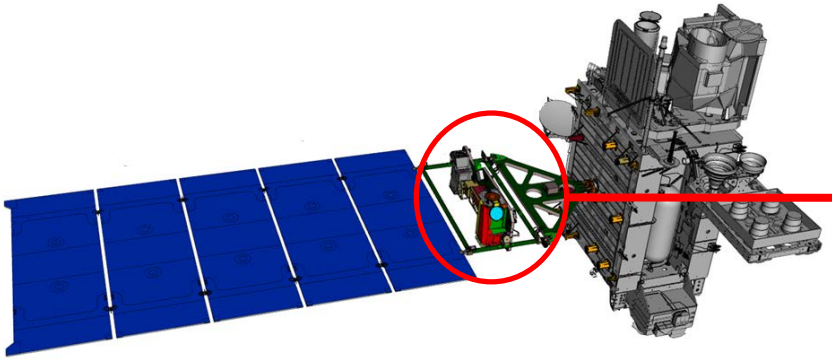
Occulter pylon optimization test

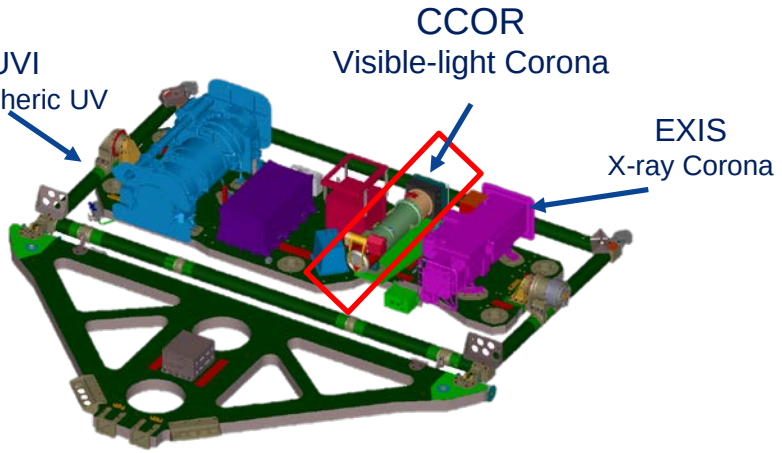
CCOR Flight 1: GOES-U

- Compact, low-mass, white-light coronagraph with decades-long heritage from NRL research: LASCO, COR1&2, WISPR, and SoloHI
- To be accommodated on the GOES-U mission to monitor CMEs from geostationary orbit starting in 2024
- Additional shielding to withstand radiation-belt effects
- Advanced on-board SEP (Solar Energetic Particle) noise scrub

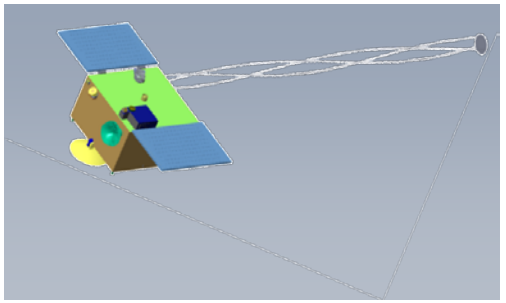
Compact **COR**onagraph (CCOR)







SWFO-L1 Spacecraft Project



3-Axis Stabilized ESPA Class Spacecraft

SWFO-L1 Mission Description

Establish operational capability and continuity of space weather observational requirements with multiple platforms.
Primary operational objectives:

- Observe Coronal Mass Ejection (CME) parameters, shape, mass and velocity
- Produce CME characteristics for input into SWPC operational heliospheric propagation code
- Measure solar wind magnetic field, plasma, and energetic particles
- Enable space weather watches and warnings

Mission Overview

- Nominal launch: 2024
- Nominal orbit: L1
- ESPA Grande compatible spacecraft
- IAA with NASA
- Rideshare with NASA IMAP

Instruments

- Solar Wind Plasma Sensor (SWiPS)
- Magnetometer
- Supra Thermal Ion Sensor (STIS)
- Compact Coronagraph (CCOR)
- Optional contributed instrument

Solar Wind Instrument Suite (SWIS)

- SWIS consists of 3 solar wind instruments:
  - Supra Thermal Ion Sensor (STIS)
  - Solar Wind Plasma Sensor (SWiPS)
  - Magnetometer (MAG)

Space Weather Operational Products Planned for SWFO

Observational Requirements Space Weather	Instrument
Solar Wind - Thermal Plasma Ion Velocity	SWiPS
Solar Wind - Thermal Plasma Ion Density	SWiPS
Solar Wind - Thermal Plasma Ion Temperature	SWiPS
Solar Wind - Solar Wind Dynamic Pressure	SWiPS
Solar Wind - Magnetic Field Vector	Magnetometer
Solar Wind - Suprathermal Ion Flux	STIS
CME White Light Intensity	CCOR
CME Velocity	CCOR
CME Direction	CCOR
CME Width	CCOR
CME Time at 21.5 Rs	CCOR
CME Mass	CCOR

SWFO-L1 Mission Space and Ground Segments

- An interagency agreement will be accomplished with NASA to procure the SWFO-L1 satellite and in-situ space weather instruments to provide the in-situ solar wind measurements
  - The CCOR instrument is being developed by NRL and will be provided as NOAA government furnished equipment
- NOAA will develop and operate the ground system to follow the NESDIS Ground Enterprise Requirements Structure
  - NWS/SWPC will continue to produce all level 1, level 2 and higher level space weather data products
  - NCEI to archive all space weather data products

Partnerships
European Space Agency (ESA)

- Possible areas of coordination include:
  - Data sharing, instrument collaboration, ground system resources, and scientific exchange

Summary

- CCOR development
  - The NRL has designed a CCOR capable of comparable performance to full size heritage units but small enough to be compatible to a variety of platforms
  - CCOR project is currently in Phase C
- Flight 1: CCOR hosted on GOES-U
  - The CCOR project is on track to be included along with other sun-viewing instruments on the GOES-U solar pointing platform
  - Nominal launch date is 2024
- Flight 2: SWFO-L1 satellite development and rideshare with NASA IMAP to Lagrangian Point 1
  - SWFO's goal is to build a satellite compatible with an EELV Secondary Payload Adapter (ESPA) Grande port which will accommodate the CCOR and the L1 in-situ SWIS
  - Plan is to rideshare with NASA IMAP on its ESPA ring for launch in 2024
  - Established interagency agreement with NASA to start development studies
- Ground segment development
  - SWFO project will leverage and/or build a distributed ground receiving and commanding network to continuously receive real-time data from both geosynchronous and L1
  - It will transmit all data to the Mission Operations Center (MOC) and SWPC
  - NESDIS concept study completed

Acronyms

CCOR	Compact Coronagraph
CME	Coronal Mass Ejection
DSCOVR	Deep Space Climate Observatory
EELV	Evolved Expendable Launch Vehicle
ESA	European Space Agency
ESPA	EELV Secondary Payload Adapter
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EXIS	Extreme Ultraviolet and X-Ray Irradiance Sensors
FOV	Field of View
GFE	Government Furnished Equipment
GOES	Geostationary Operational Environmental Satellite
IAA	Interagency Agreement
IMAP	Interstellar Mapping and Acceleration Probe
L1	Lagrange 1
L5	Lagrange 5
LASCO	Large Angle and Spectrometric Coronagraph
MAG	Magnetometer
MOC	Mission Operations Center
NASA	National Aeronautics and Space Administration
NCEI	National Centers for Environmental Information
NESDIS	NOAA Satellite and Information Service
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NSOSA	NOAA Satellite Observing System Architecture
PDR	Preliminary Design Review
RTSW	Real Time Solar Wind
SEP	Solar Energetic Particles
SOHO	Solar and Heliospheric Observatory
SoloHI	Solar Orbiter Heliospheric Imager
STEREO	Solar TErrestrial RElations Observatory
STIS	Supra Thermal Ion Sensor
SUVI	Solar Ultraviolet Imager
SWFO	Space Weather Follow-On
SWiPS	Solar Wind Plasma Sensor
SWIS	Solar Wind Instrument Suite
SWPC	Space Weather Prediction Center
UV	Ultra Violet
WISPR	Wide-Field Imager for Solar Probe Plus