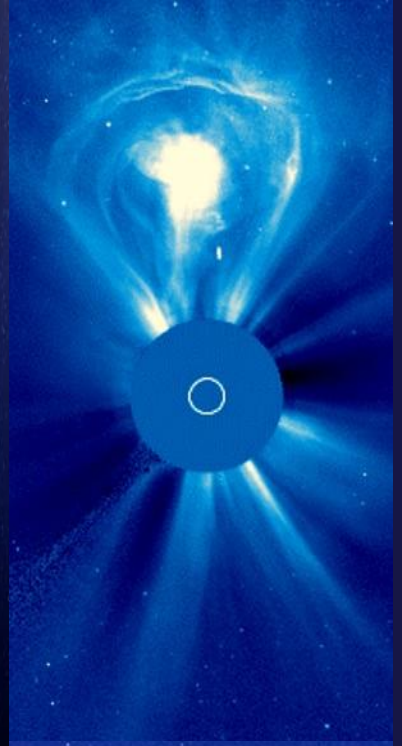

The CCOR Series of Compact Coronagraphs for Space Weather Forecasts

Natsuha Kuroda[1], Arnaud Thernisien[2], Damien Chua[2], Tim Carter[2], Nathan Rich[2], John Spitzak[3], Larry Gardner[4]

4th Eddy Cross-Disciplinary Symposium, 10/31/2023

[1] George Mason University
[2] US Naval Research Laboratory
[3] CPI
[4] SSRC

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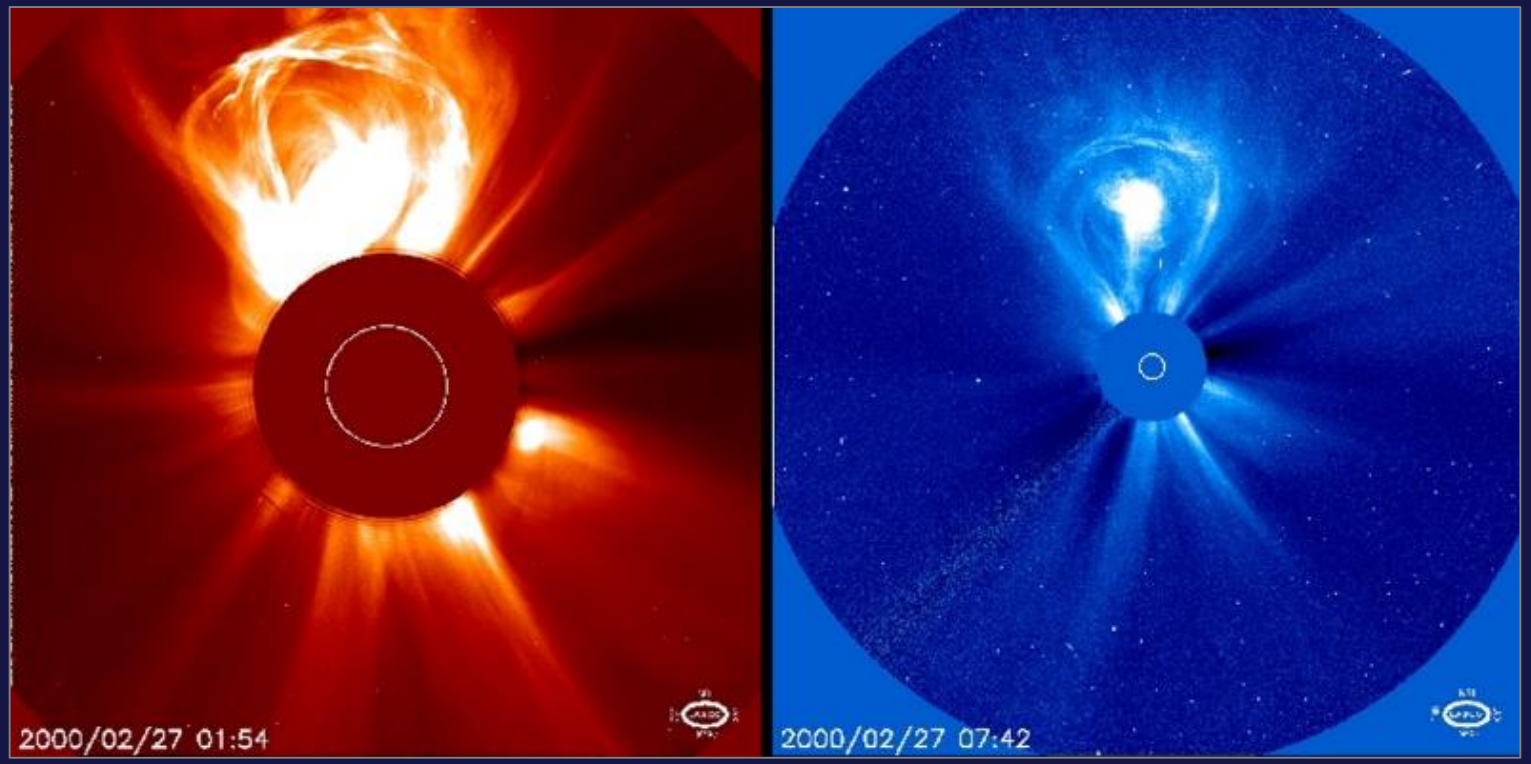
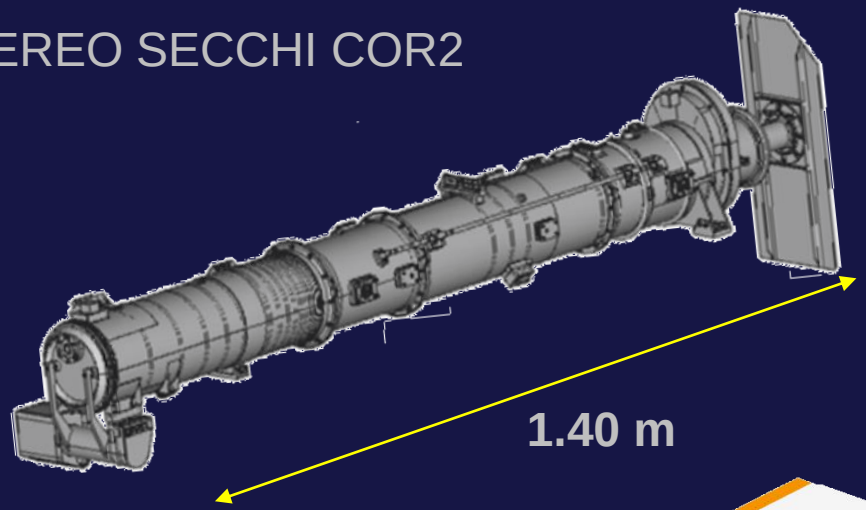
Coronal Mass Ejections & Space Weather

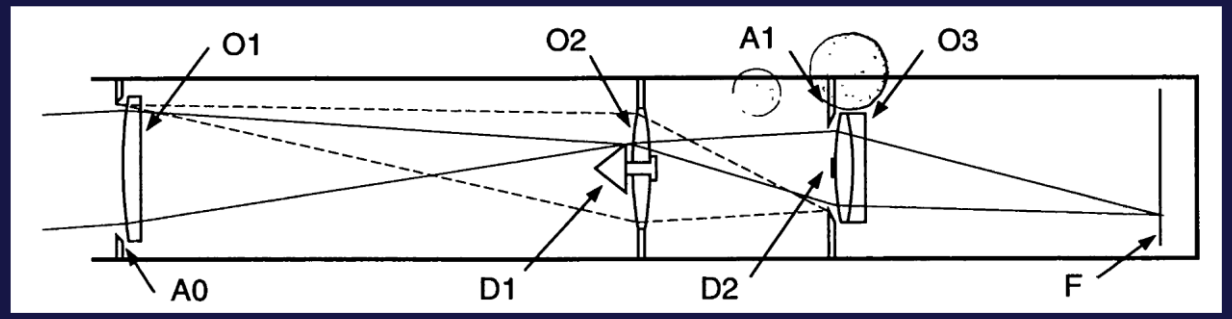


- Outburst of solar plasma and magnetic field from the corona.
- CME interactions with the Earth's magnetosphere induce global-scale perturbations in the near-Earth space environment, which impacts:
  - Electric Power Transmission
  - Navigation Systems
  - HF Radio Communications
  - Satellite Drag

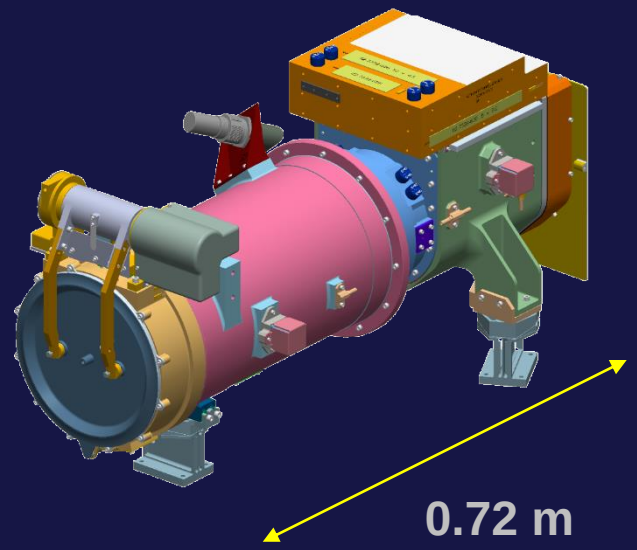
Lyot Coronagraph Compared to NRL CCOR

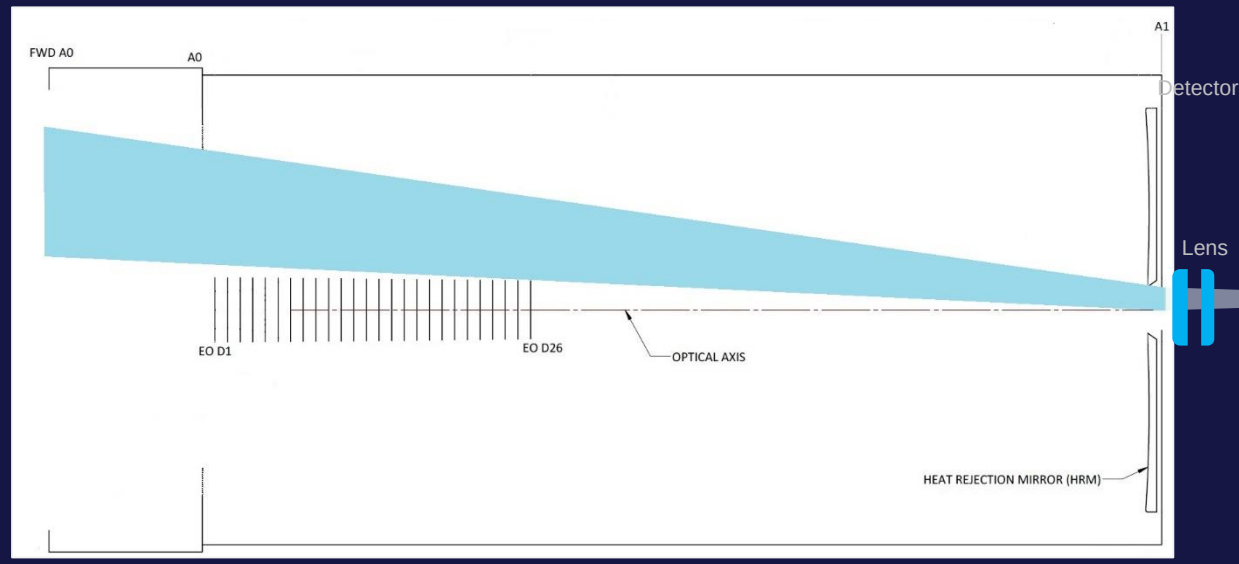
STEREO SECCHI COR2





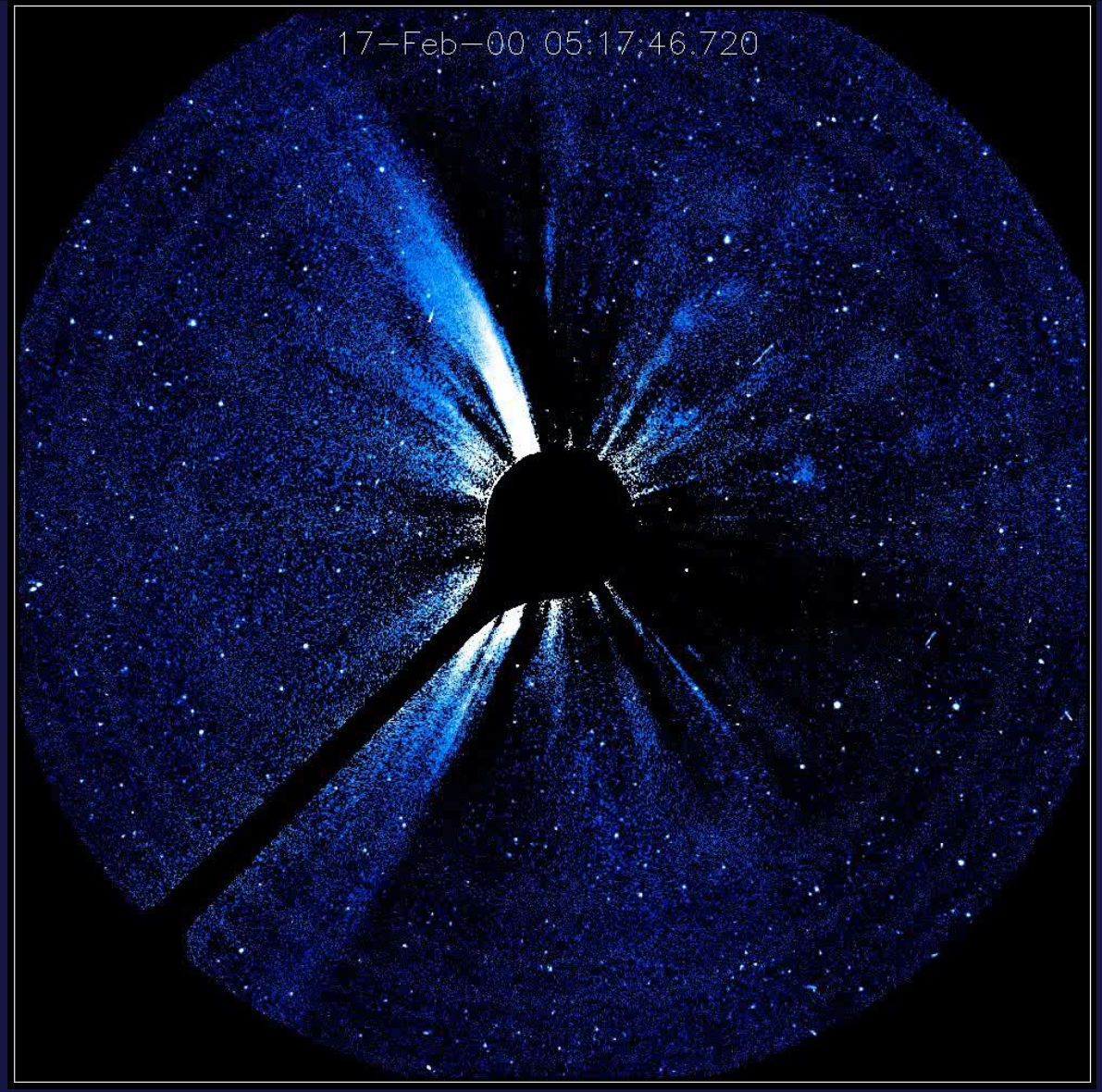
CCOR-2 (SWFO-L1)

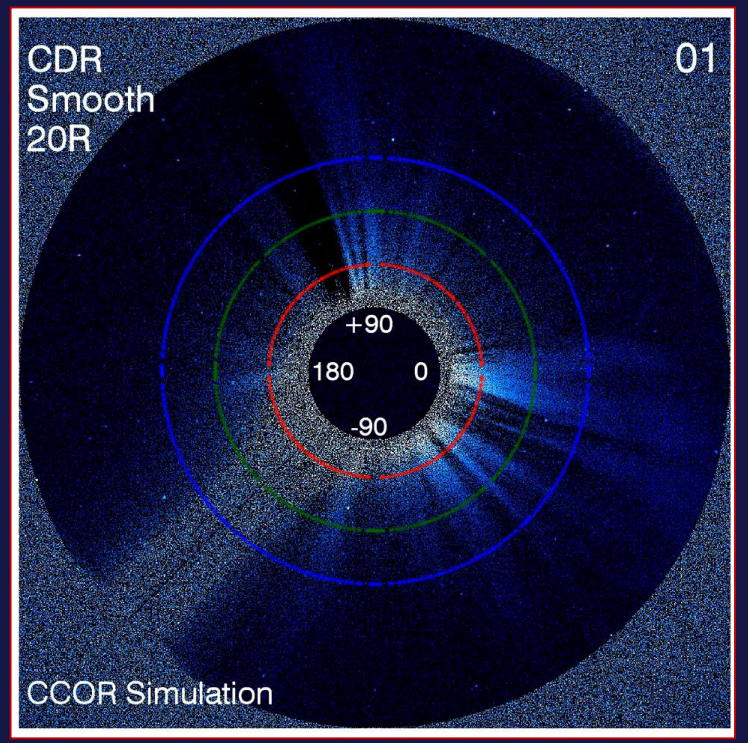




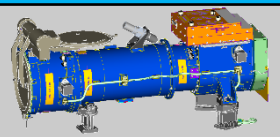
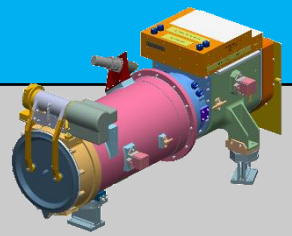
CCOR achieves the same level of diffracted stray light rejection as SECCHI COR2.

CCOR-1 Proxy Movie, Based on LASCO-C3





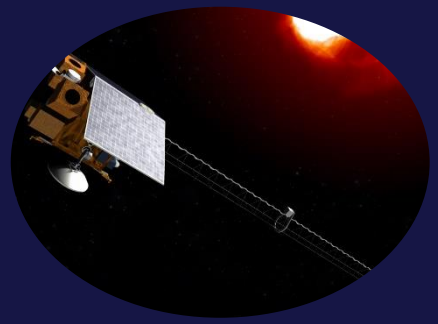
CCOR Performance Requirements

Specifications	Requirements		
	CCOR-1 	**CCOR-2** **CCOR-3** 	LASCO C3 (actual spec)
Spacecraft	GOES-U	SWFO-L1	SOHO
Bandpass	**450 – 750 nm**		400 – 1050 nm
FOV	**3.7 to 17.0 R_{Sun}**	**3.0 to 22.0 R_{Sun}**	3.7 to 30.0 R_{sun}
Spatial resolution	50 arcsec	70 arcsec	56 arcsec
Image size	2048 × 1920 pixels		1024 x 1024 pixels
Cadence	**15 minutes**		Hours ~ 6 minutes
CME Velocity	**200 – 3400 km s^{-1}, 5% accuracy**		~50 to > 3000 km s^{-1} (1996 – Nov. 2021)
Photometric accuracy	< 10 %		~ 7 % (1996 - 2006)
Minimum corona intensity	**≥ 1.0 × 10^{-11} B_{Sun}**		1.0 × 10^{-11} B_{Sun}

NRL Compact Coronagraph (CCOR)

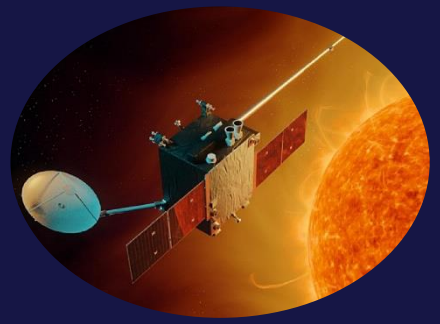
GOES-U (NOAA)
CCOR-1

2024



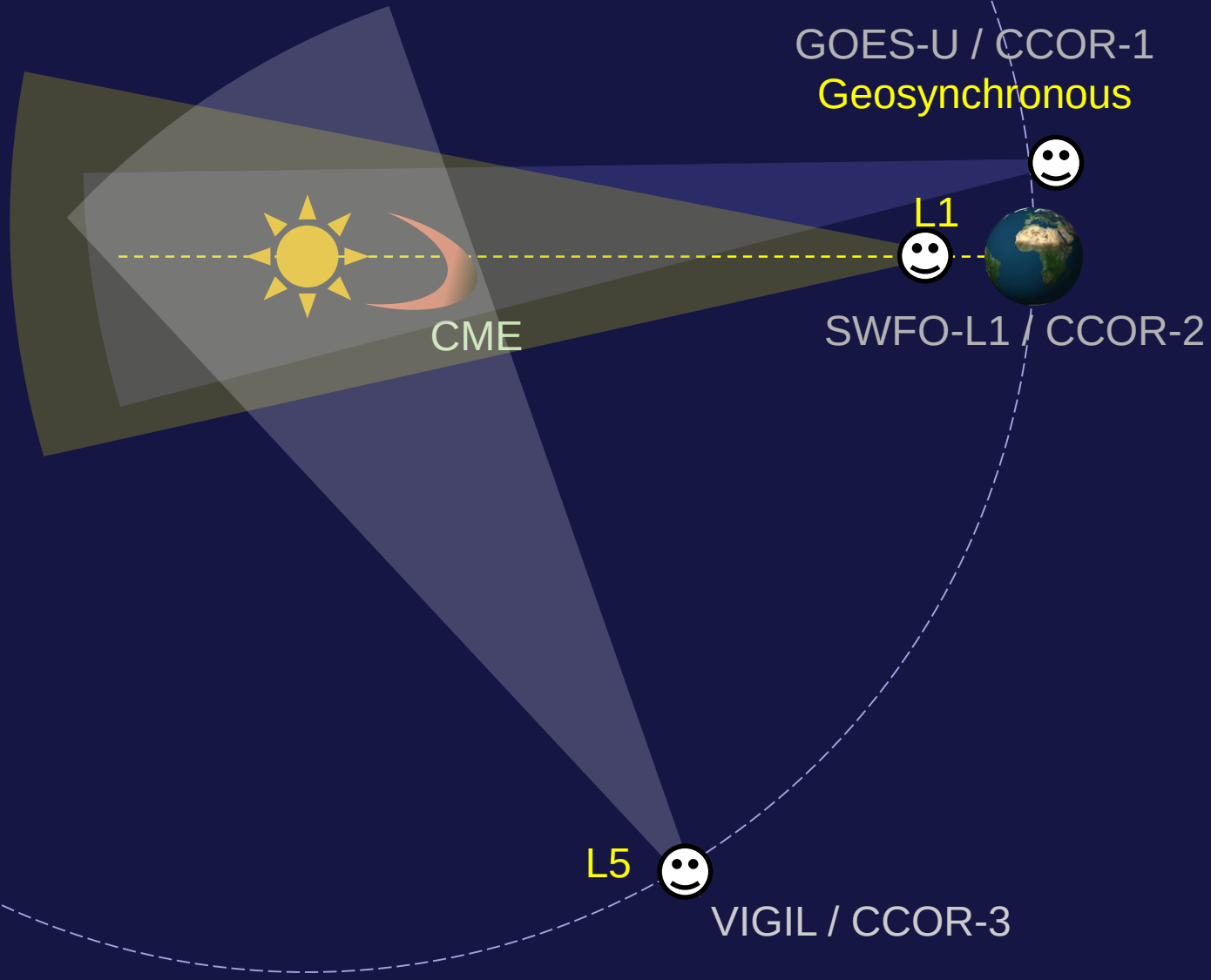
SWFO-L1 (NOAA)
CCOR-2

2025



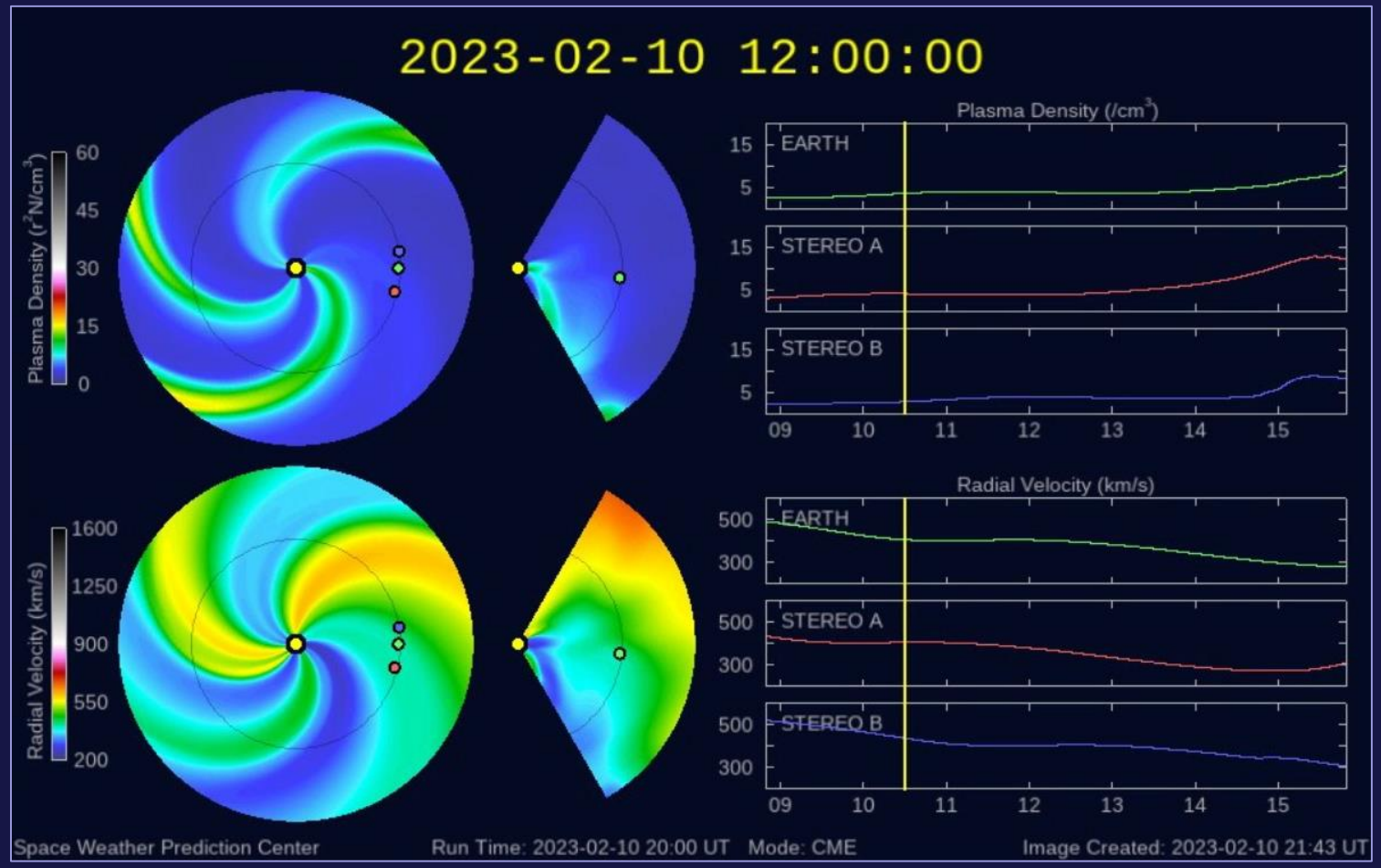
Vigil (ESA)
CCOR-3

2029



CCOR Images for Forecasting

Wang-Sheeley-Arge Enlil (WSA-Enlil) solar wind / heliosphere model, NOAA Space Weather Prediction Center (SWPC)



- CCOR Data Products:
  - CME width
  - CME mass
  - CME velocity
  - CME direction
- Issue geomagnetic storm watches, warnings.
- Issued to 50,000+ users.
- Critical storm warnings are communicated directly to power grid operators and FEMA.

Risk & Resiliency to Space Weather Disruption/ Continuity for Operational Solar Coronagraphs

- CME imagery from coronagraphs have improved successful geomagnetic storm forecasts from 27% to 60%.
- Reduction in uncertainty in CME arrival times from ±12 hours to ±7.5 hours.
- Having images from multiple viewpoints is crucial in reducing CME arrival time error:
  - 3-viewpoints vs. less = 9.6 ± 0.8 hours vs. 11.6 ± 1.4 hours
  - "We find 'single viewpoint' cone analysis, while a useful start, to be highly problematic in many real-world situations." (Millward 2013)

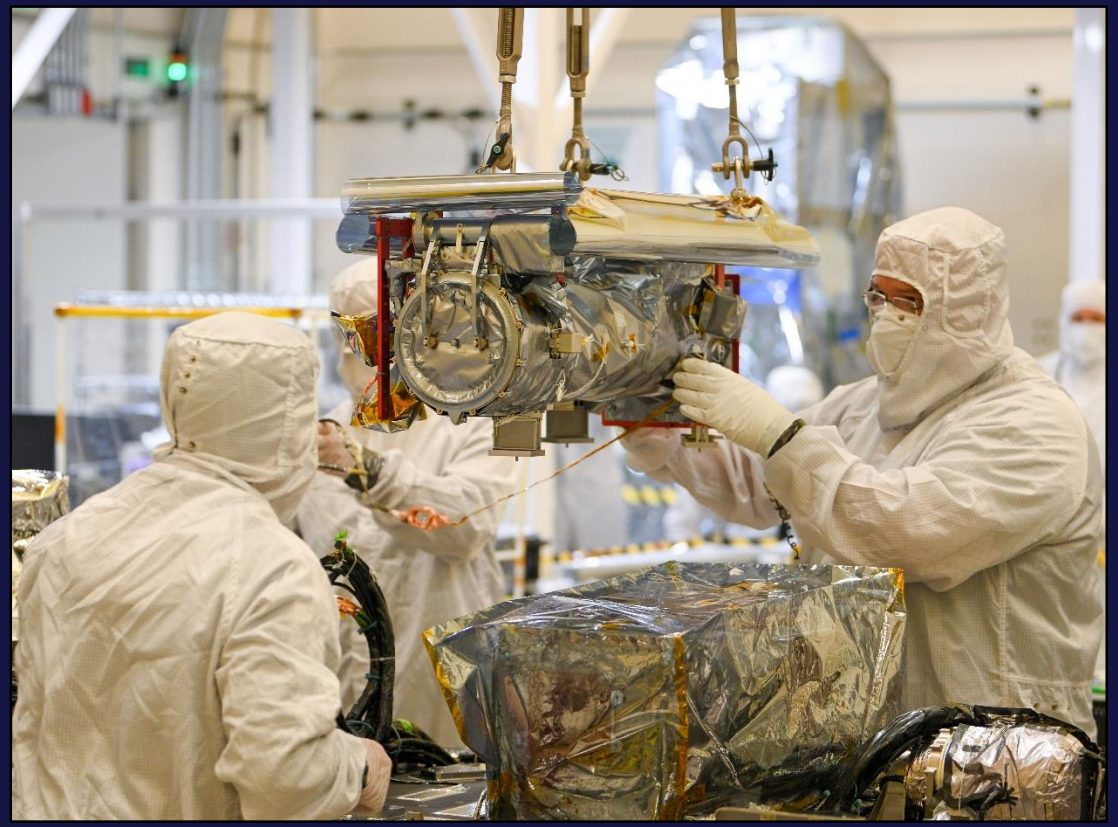
- Having multiple space-based coronagraphs is essential in today's space weather forecasting
- Operational solar coronagraphs give the earliest possible notice of impending geomagnetic activity, thus providing the longest possible lead time for geomagnetic storm watches

We're hiring!! ☺

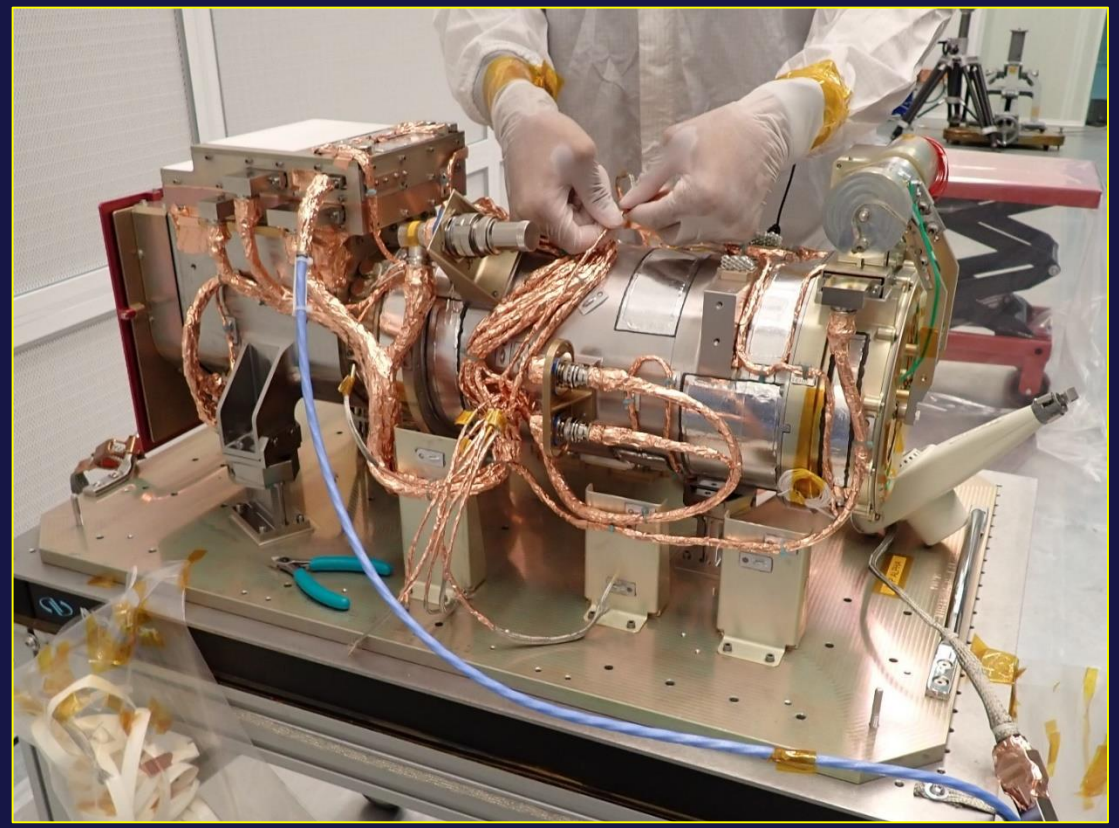
- Level: PhD in physics, optics, image and data processing.
- Experience in data analysis of solar physics data preferable, but not required. Some experience in image processing, and/or astronomy data processing.
- The candidate should be US citizen, or resident (Green Card).

Please contact Arnaud Thernisien, arnaud.thernisien@nrl.navy.mil.

CCOR-1 integrated on GOES-U (Jan 2022)



CCOR-2 at NRL (Mar 2023)



Thank you for your attention!