Compact Coronagraph (CCOR) Accommodation on GOES-U

Renee P. Dudley[1], Alexander Krimchansky[2], Sivakumara K. Tadikonda[3], Arnaud F Thernisien[4], Rebecca A. Baugh[5], Melissa Dahya[1], Dimitrios Vassiliadis[6], Clarence Korendyke[5] (1) Aerospace Corporation, Greenbelt, MD, (2) National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD, (3) Science Systems & Applications, Lanham, MD, (4) US Naval Research Laboratory, Washington, DC, (5) Space System Research Corporation, Alexandria, VA (6) National Oceanic and Atmospheric Administration, Silver Spring, Maryland

Abstract

The CCOR-1 will monitor our Sun's Coronal Mass Ejections (CMEs). It will reside on the Sun-Pointing Platform (SPP) of the Geostationary Operational Environmental Satellite (GOES)-U in a geostationary orbit. As a member of the GOES-R Series of satellites, GOES-U will provide advanced imagery and atmospheric measurements of Earth's weather, oceans and environment, real-time mapping of total lightning activity, and as well as monitoring of solar activity and space weather. GOES-U is the final satellite in the GOES-R Series, with an expected launch date in April of 2024.

The Compact Coronagraph (CCOR) instrument was designed, built, and tested by the United States Naval Research Laboratory. CCOR-1, the first in a series of coronagraphs, is funded by the National Oceanic and Atmospheric Administration (NOAA), is managed by the National Aeronautics and Space Administration (NASA), and will ultimately be operated by NOAA. Using a series of images of the Sun's coronal white-light, scientists at NOAA's Space Weather Prediction Center (SWPC) and National Centers for Environmental Information (NCEI) can determine the size, velocity, and density of these CMEs. This information can then be used to assess and prepare for potential impacts of these solar storms on infrastructure here on Earth, as well as assets in space.

CCOR-1 has completed instrument-level Integration and Testing (I&T), delivered to the GOES-U satellite vendor and is now mechanically integrated with the spacecraft. The GOES-U satellite has completed spacecraft-level integration and test activities.

This poster presents the details on the CCOR-1 instrument, its integration onto the GOES-U satellite bus, ground system, and operations, as well as the expected performance.

Purpose

- Provide operational, low latency detection, characterization, and tracking of Coronal Mass Ejections (especially Halo CMEs) to NOAA's SWPC.
- Geomagnetic storms are major disturbances of Earth's magnetosphere caused by the entry of the solar wind's magnetic and kinetic energy into the magnetosphere. Geomagnetic storms are the costliest type of space weather events as they can cause widespread damage to power grids, satellites, and communication and navigation systems. CMEs are the primary cause of large geomagnetic storms.
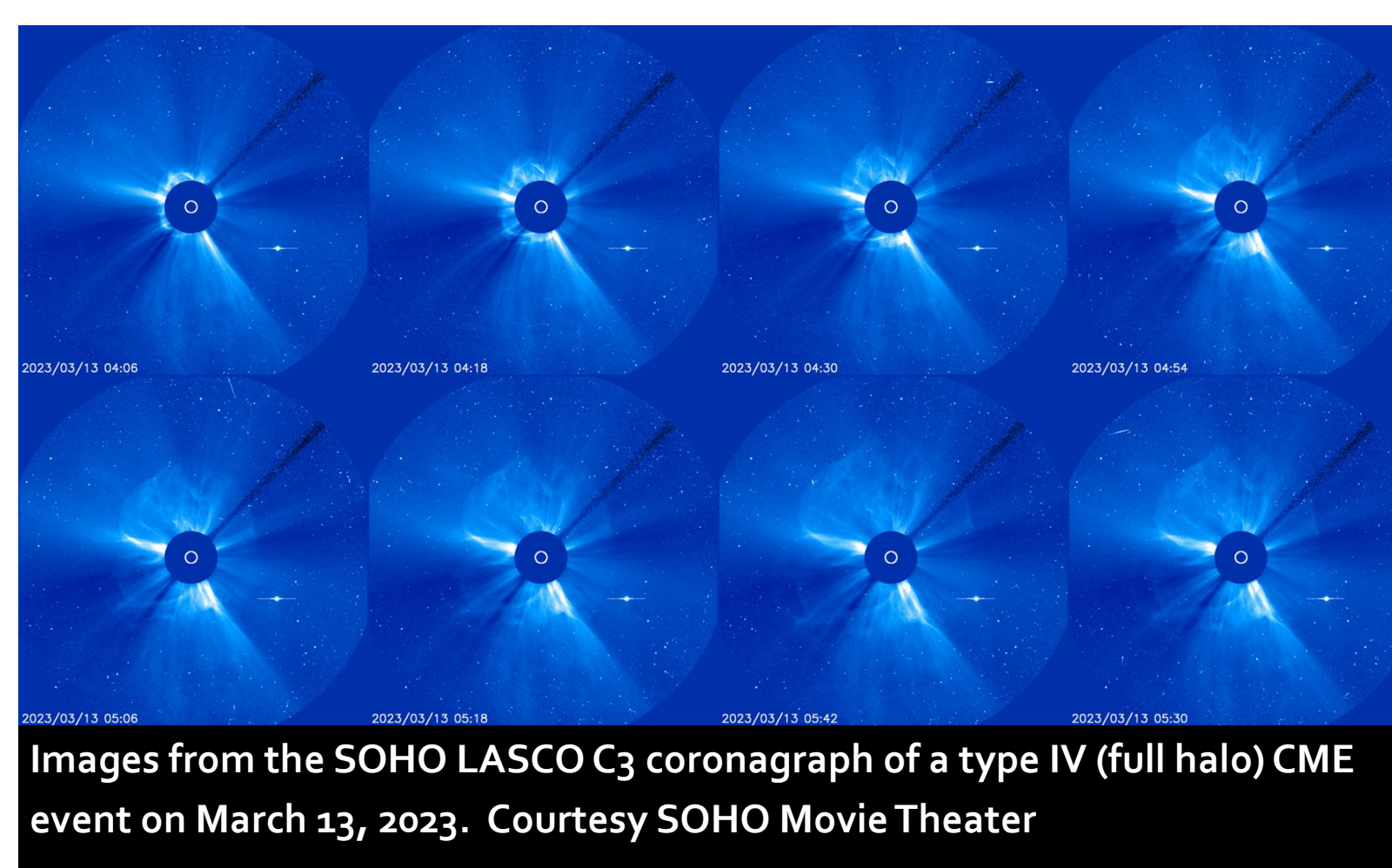
Images from the SOHO LASCO C3 coronagraph of a type IV (full halo) CME event on March 13, 2023. Courtesy SOHO Movie Theater

- Provide, in combination with other sensors, early warning and forecast of space weather events.
- CCOR will overlap and eventually replace Large Angle and Spectrometric Coronagraph (LASCO) instrument on board the European Space Agency (ESA)/NASA Solar and Heliospheric Observatory (SOHO) satellite, launched in 1995.
- As part of NOAA's Space Weather Follow-On (SWFO) Program CCOR was developed at the Naval Research Laboratory to ensure continuity of critical CME imagery

Driving Requirements

Driving Requirements	
Key Performance Parameter (KPP)	Coronal White Light Intensity Data (480 to 730 nm)
Field of View Coverage	$\leq 3.7 R_{sun}$ to $\geq 17 R_{sun}$
Coronal Observation: Min Intensity	$\geq 1.0e^{-11}B_{sun}$
Coronal Observation: Max Intensity	$\leq 1.0e^{-8}B_{sun}$
Coronal Observation: Brightness Meas Accuracy	>10 Signal to Noise Ratio
Coronal Observation: Refresh Rate	≤ 15 minutes
Image Data to Forecaster Latency	≤ 30 minutes after observation
Latency of Image Transfer to S/C	≤ 12 minutes
Data Delivery	80% over 30 days, excluding eclipse periods
CME Imagery Availability during Solar Storms	through an intensity of S4
CME Imagery Availability during Solar Flares	up to an intensity of X50
KPP Initial Operational Capability	≤ 6 months from start of operations
Mission Life	5 years + 5 years additional resources
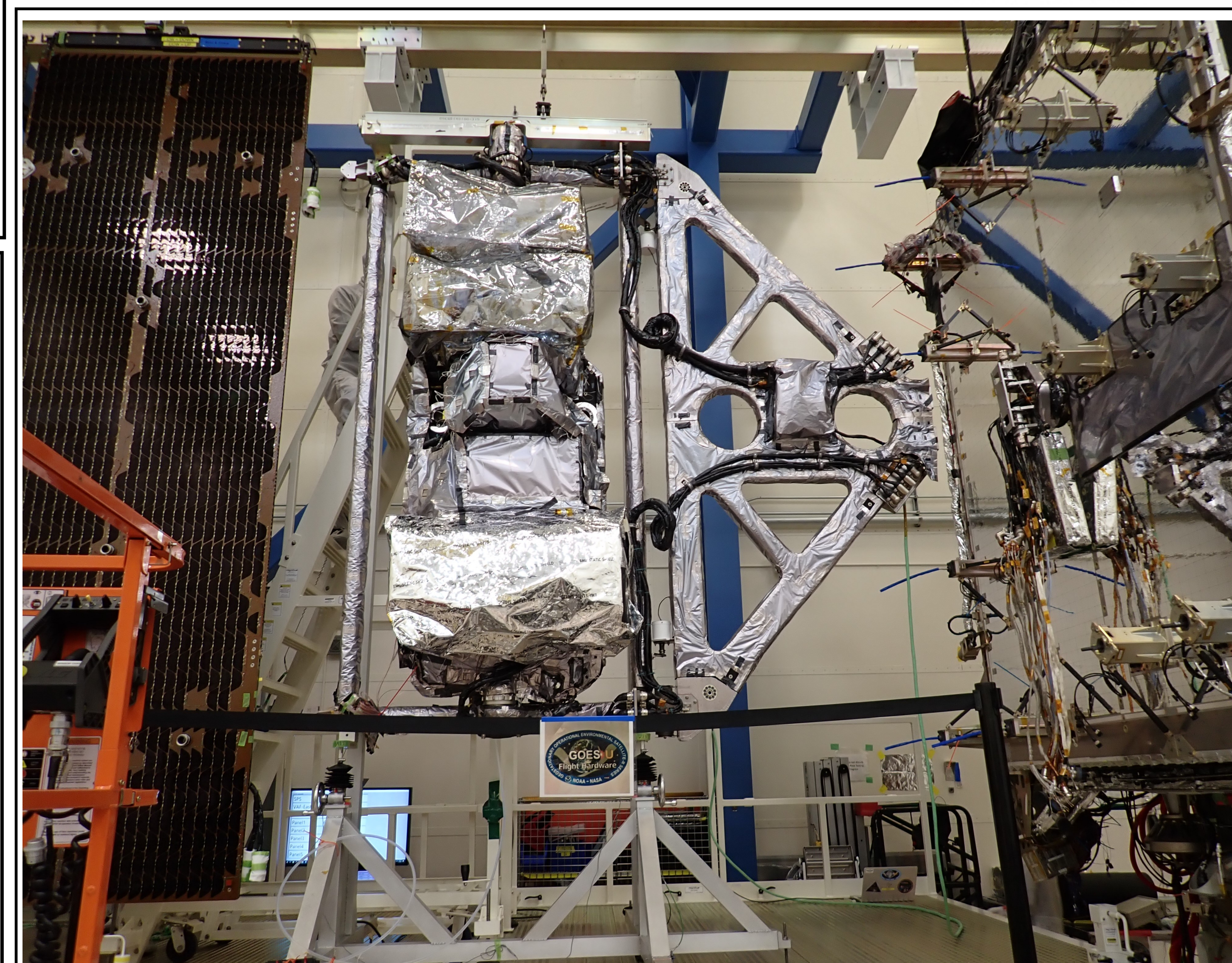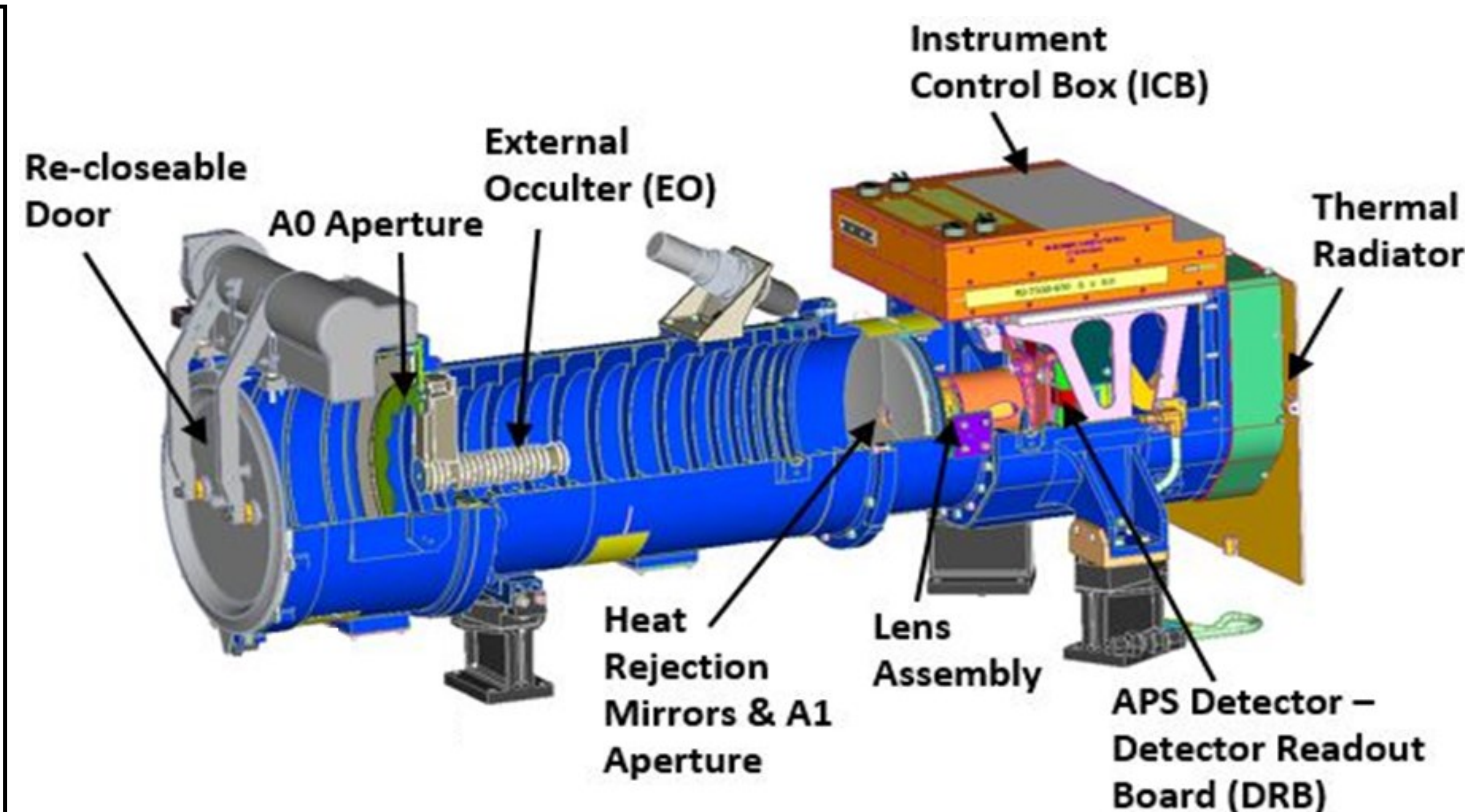
GOES-U Solar Pointing Platform at the Lockheed Martin High Bay in Waterton, Colorado. From the top going down the instruments include: EXIS, CCOR, CCOR PSB, SUVI SEB, and SUVI STS. Image courtesy Lockheed Martin.

High Level Ground Segment Architecture
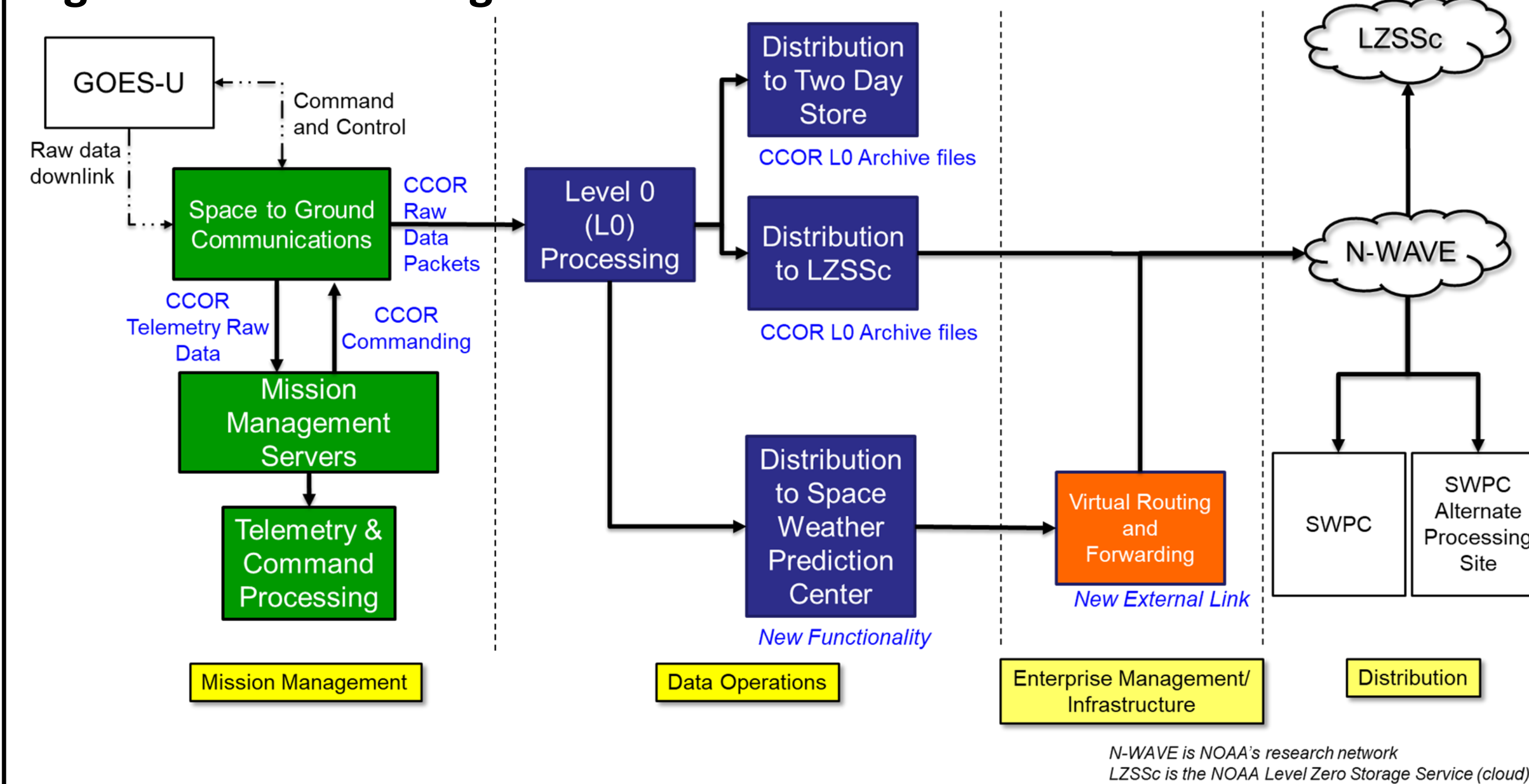
N-WAVE is NOAA's research network
LZSSc is the NOAA Level Zero Storage Service (cloud)

Spacecraft

- Design Modification Reviews (DMR) were conducted for integration onto GOES-U Spacecraft Solar Pointing Platform (SPP)
- CCOR-1 electrically and mechanically integrated onto the SPP at Lockheed Martin in February 2022
  - SPP Layout was modified to provide area for CCOR and its Power Supply
  - Spacewire reallocation of SUVI cross-strapping to CCOR
  - Spare Solar Interface Unit channels/harness/connector for critical telemetry
  - 28V power capacity allocated to CCOR
- Updates made to the GOES-U satellite simulator, software testbed, database, operational and contingency procedures, and flight software
  - Flight Software validation testing performed using the Satellite Simulator/ CCOR Emulator
  - Full Mission System Validation Test (SVT) second quarter 2023 (Test Like You Fly Full Operational Scenario of satellite)
- GOES-U has completed the majority of its environment testing, including Thermal Vacuum and Vibration/Shock; EMI/EMC is scheduled later this summer
- Software performance tested throughout the environmental test campaign.

SPP Layout Design for GOES-U
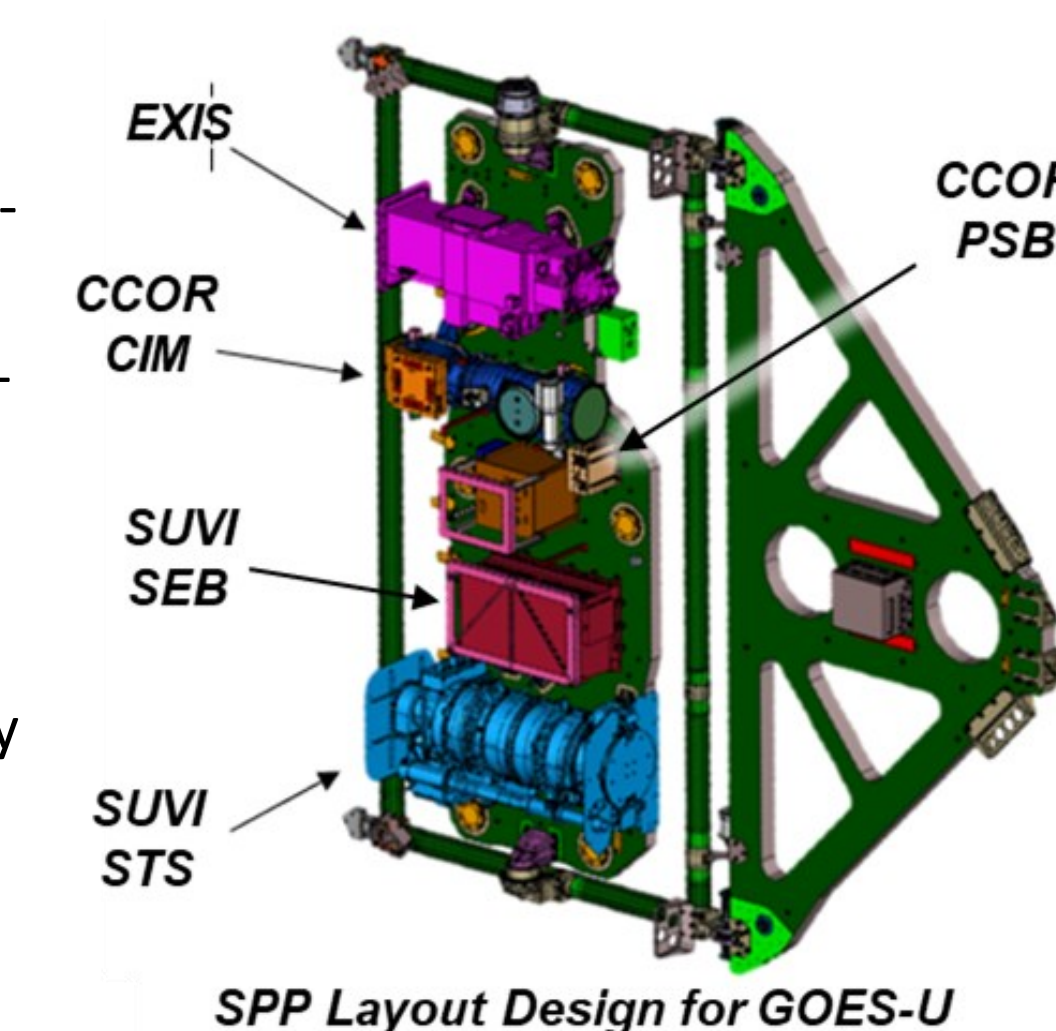
Ground System

CCOR functionality is hosted on the existing GOES-R Ground System
- Leverages existing ground system architecture for availability and redundancy, no new hardware
- Utilizes existing, established processes for verification and validation of Ground Segment software updates related to CCOR

Mission Management related updates deployed and tested in Spring 2023
- Command and Control
  - Formatting of instrument commands, including memory management
  - Receipt and processing of CCOR raw telemetry data
  - Receipt and check of CCOR science data packets
- Mission Planning and Scheduling
  - Integrate CCOR related tasks into the GOES-U schedule

Data Operations related updates deployed and tested in Spring 2023
- Level 0 (L0) data is distributed to the NOAA Level Zero Storage Service in the Cloud (LZSSc) for retrospective users
- Level 0 (L0) data and housekeeping data distributed to the SWPC for the near real-time generation of Level 1b and Level 2+ products

Enterprise Management/Infrastructure is being updated to support data transmission to SWPC; successful connectivity and data flow testing began in Fall 2022

Mission Operations

Mission Operations leverages existing processes and infrastructure for CCOR-1 Support
- The Mission Operations Support Team (MOST) is a highly experienced team that has launched, tested, and operated three GOES-R spacecraft. The MOST:
  - Receives training from NRL on all aspects of CCOR operations
  - Prepares and executes End-to-End testing to validate compatibility of flight and ground hardware, software, and communication interfaces in a mission operations in a "test-like-you-fly" context
  - Prepares and executes Mission Rehearsals and other informal simulations to prepare for instrument operations during Launch and Orbit Raising, deployments, Post Launch Testing, calibrations, normal and contingency operations
  - Collaborates with NASA, NRL, NOAA SWPC and NCEI Subject Matter Experts in preparation of Post Launch Testing and Calibration procedures
  - Works with NRL to generate operational products: command procedures, display pages, trending data, testing scripts, operational and contingency procedures
  - Performs all CCOR operations and monitors the health and safety of the instrument (with NRL support) from launch through handover to NOAA for operations

CCOR related operational activities on GOES-U include:
- Non-eclipse: Nominal daily schedule runs without user input
- Eclipse: Schedules loaded daily to accommodate imaging in shadow. Spacecraft yaw flip will be executed at the beginning of each eclipse season and will include a pause for CCOR calibration activities

Links and References

[1]: "The CCOR Series of Compact Coronagraphs for the Space Weather Follow-On Program", AGU Fall Meeting 2022, held in Chicago, IL, Dec. 2022, id SH55D-1538
[2]: GOES-R Program Website, https://www.goes-r.gov/spacesegment/CCOR.html
[3]: SOHO Movie Theater, https://soho.nascom.nasa.gov/data/Theater/
[4]: GOES-R Series Mission Operations Plan, November 2021, 417-R-MOP-0237
[5]: GOES-U CCOR Flight Operations Peer Review, December 2022