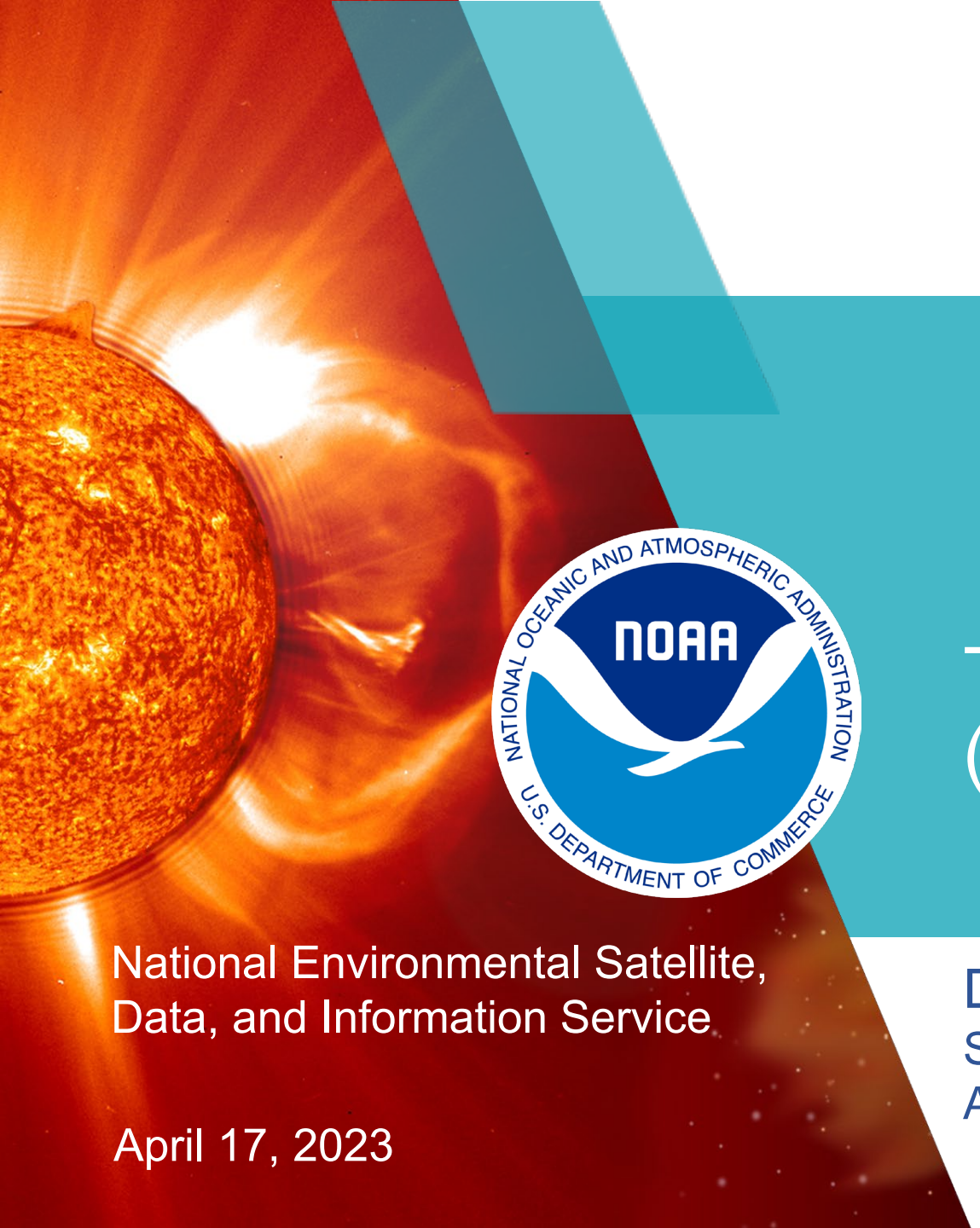

The Space Weather Follow On (SWFO) Program: Introduction

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SWFO Product Generation and Distribution lead

Acting SWFO Scientist

National Environmental Satellite, Data, and Information Service

April 17, 2023

NOAA: Responding to User Needs for Space Weather Information

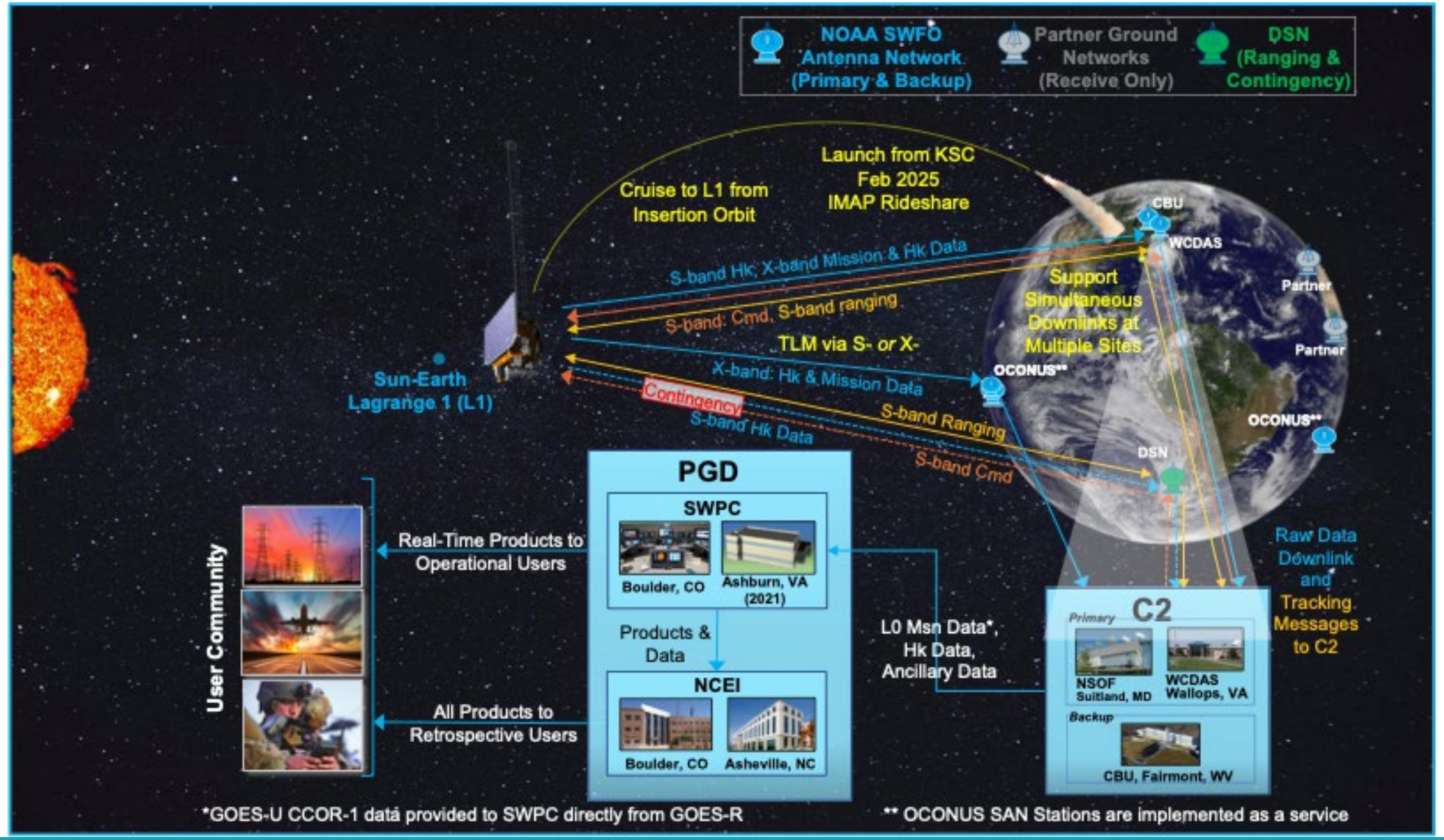
- Awareness of the near-Earth space environment is crucial for a wide range of users. The lack of space weather specification and forecasts reduces efficiency and increases cost and risk in many different industry sectors that rely on satellite and other services.

- NOAA has the responsibility of providing such space weather information to its users. Since several monitoring satellites have a limited remaining lifespan (SOHO, ACE, DSCOVR) it is important to plan for follow-on missions for solar, heliospheric, and other observations.

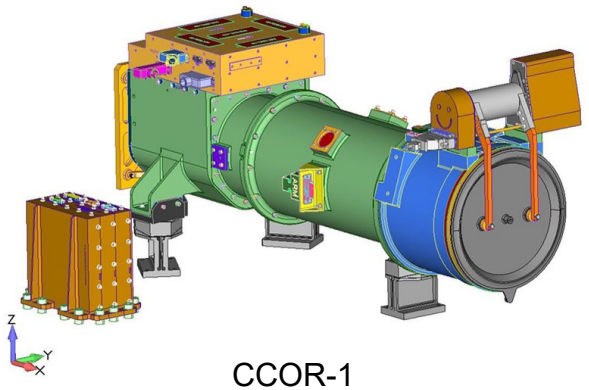
The Space Weather Follow On (SWFO) Program

- The Space Weather Follow On (SWFO) Program has been developed with the goal of providing high-quality coronal imaging and solar wind measurement capabilities to ensure continuity of critical data.
- SWFO's Flight Segment comprises the following components
  - The Compact Coronagraph (CCOR) on the GOES-U satellite (launch: 4/2024)
  - The SWFO-Lagrange 1 (SWFO-L1) Observatory (launch: 2/2025).
- SWFO will provide the following products:
  - Coronal imagery will be the basis of early situational awareness for long-term forecasting
  - Solar wind and interplanetary magnetic field measurements will be used as inputs to magnetospheric models.
  - Particle flux measurements will be used to improve estimates of the solar wind arrival time.

Concept of Operations for SWFO-L1

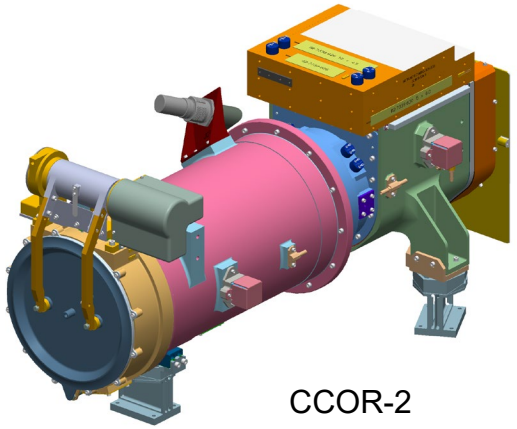


SWFO: Heliophysics Instruments

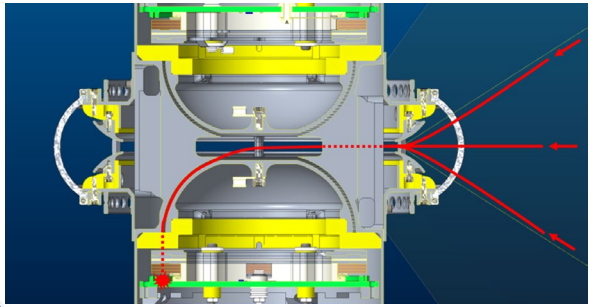


CCOR-1

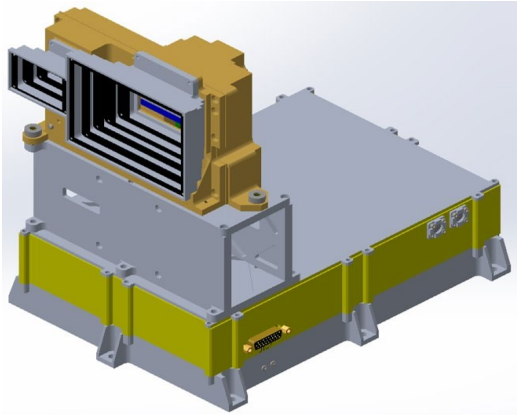
Compact Coronagraphs (CCORs): Developed by the Naval Research Lab (NRL), the telescope will be used to observe the solar corona and detect coronal mass ejections (CMEs),CIRs and other structures. CCOR-1 will fly on the GOES-U satellite (2024) and a nearly identical CCOR-2 on SWFO-L1 (2025).


CCOR-2

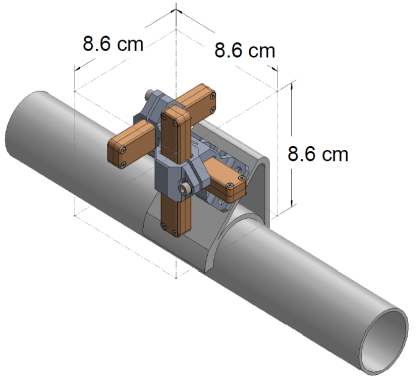
Solar Wind Plasma Sensor (SWiPS): Built by Southwest Research Institute (SwRI), it will measure properties of the solar wind flowing past SWFO-L1, such as density, velocity, and temperature.



Suprathermal Ion Sensor (STIS): Developed by University of California, Berkeley, it will collect fast ions in the solar wind.



Magnetometer (MAG): Developed by the University of New Hampshire and SwRI, it will measure the interplanetary magnetic field.

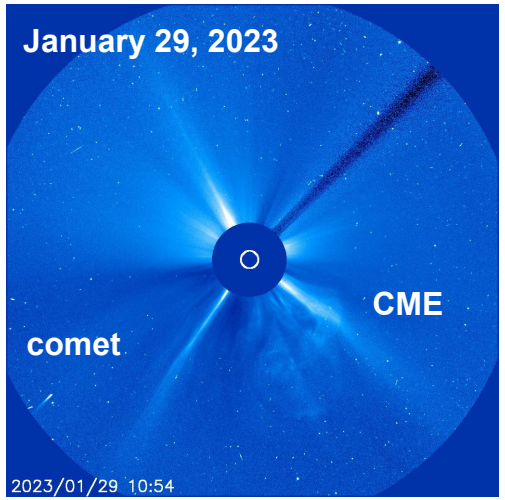


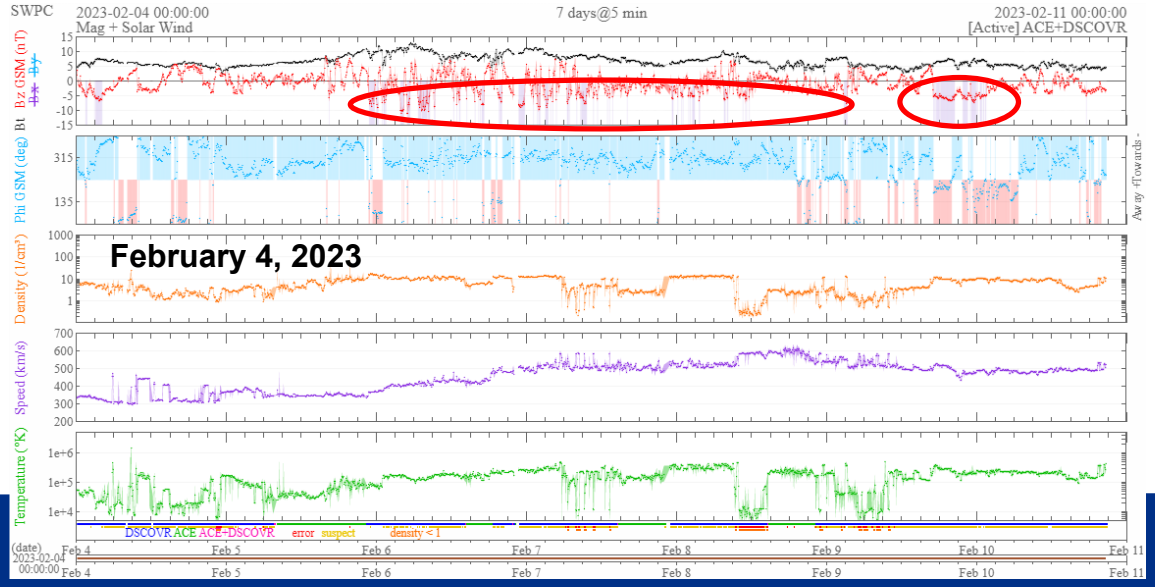
SWFO Product Generation and Distribution

SWFO PGD will enable the following data products and space weather services:

1. Processing of L0 datastreams into science products:

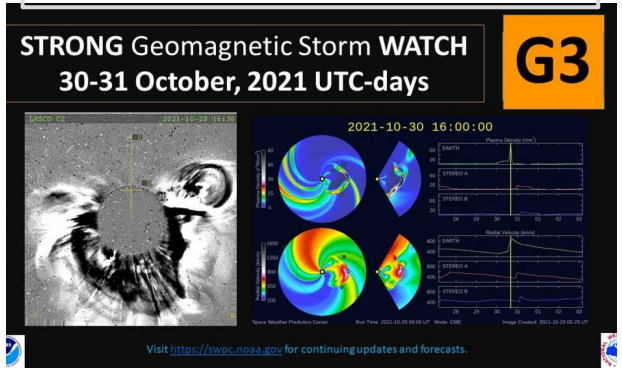
- Coronal images: From SOHO LASCO/C3 to GOES-U/CCOR-1 and SWFO-L1/CCOR-2
- Time series of solar wind plasma and magnetic field: From DSCOVR/FC, MAG and ACE/EPAM to SWFO-L1/SWiPS, MAG STIS



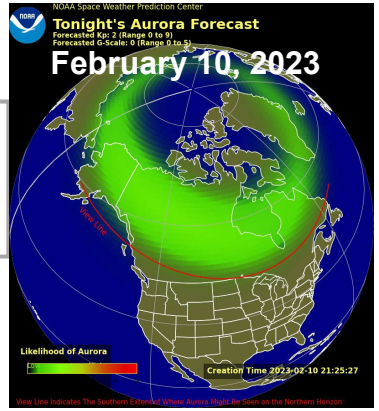


2. Immediate use of the products in providing situational awareness and in reliably driving real-time models. Thus, the data will result in SpWx nowcasts and forecasts.

Heliospheric model and forecast

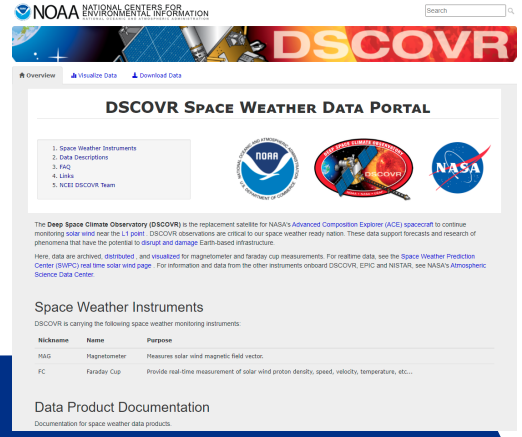


Auroral model and forecast



3. Archiving of data to enable access by the science community and numerous other users.

From the DSCOVR Data Portal to the SWFO Science Center)



SWFO: Enabling Research

- Images and data from the SWFO-L1 observatory and the CCOR-1 on GOES-U will enable research in several areas continuing the SOHO, DSCOVR, and ACE capabilities:

1. Connections between the inner heliosphere and the 1-AU region. Monitoring the radial evolution of CMEs, HSSs, helmet streamers/pseudostreamers, fluxropes, and other structures as they propagate through the SW, and the associated particle acceleration.
2. Initial phase of CME acceleration in the low corona; fits to GCS and other models; relation to activity measures such as magnetic-field and SEP flux.
3. Driving of environmental models: global-MHD, radiation belt empirical and diffusion models, ionospheric, others. Geoeffectiveness of solar wind structures (CMEs, etc.).
4. Data analysis of plasma-moment, IMF, and/or particle flux for: a) Solar wind structure identification; b) Time evolution of particle energy spectra; c) Electric-field/other input to dayside magnetosphere reconnection models; d) Solar wind invariants, cascades, and dissipation mechanisms; e) power-law (fractal) and other distributions.
5. Solar system astronomy: sungrazer comet detection, zodiacal dust parameter estimation.
6. Statistical and long-term studies: solar cycle, space climate.
7. Other: Data assimilation, machine learning, etc.

- **Relevant SHINE WGs**: 1 (Solar, coronal), 2 (Interplanetary), 3 (SEPs).

Products, Latency, Availability

- The SWFO main products are shown on the right. The highest-priority products are the Key Performance Parameters (KPPs).
- The Initial Operational Capability (IOC) of the program is based on the generation of KPPs at Levels 1 to 3 and delivery to users.
  - Higher-level products are planned at SWPC.
- Data latency requirements: Products will be made available at 5 minutes for solar wind data and 30 minutes for coronal imagery.
- Data availability requirement (program-level): 96%.

Space Weather Data Product	KPP
Coronal White Light Intensity	Y
Thermal Plasma Ion Velocity	Y
Thermal Plasma Ion Density	N
Thermal Plasma Ion Temperature	N
Vector Magnetic Field	Y
Suprathermal Ion Differential Flux	N
Dynamic Pressure	N

Performance Requirements: CCOR

Specifications	Requirements	
	CCOR-1	**CCOR-2**
Requirement Doc. (PORD*)	SSD-RQT-CC007 Rev. A	SSD-RQT-CL004 Rev. -
Spacecraft	GOES-U	SWFO-L1
Bandpass	WL: 450-750nm	WL: 450-750nm
FOV	3.7 to 17 Rsun	3.0 to 22 Rsun
Spatial resolution	50 arcsec	70 arcsec
Image size	2048x1920 pixels	2048x1920 pixels
Cadence	15 min	15 min
Latency	< 12 min	≤ 18 min
Photometric accuracy	< 10 %	< 10 %
Minimum corona intensity	≥1.0e-11 Bsun	≥1.0e-11 Bsun

*** PORD: Performance Operational Requirement Document**

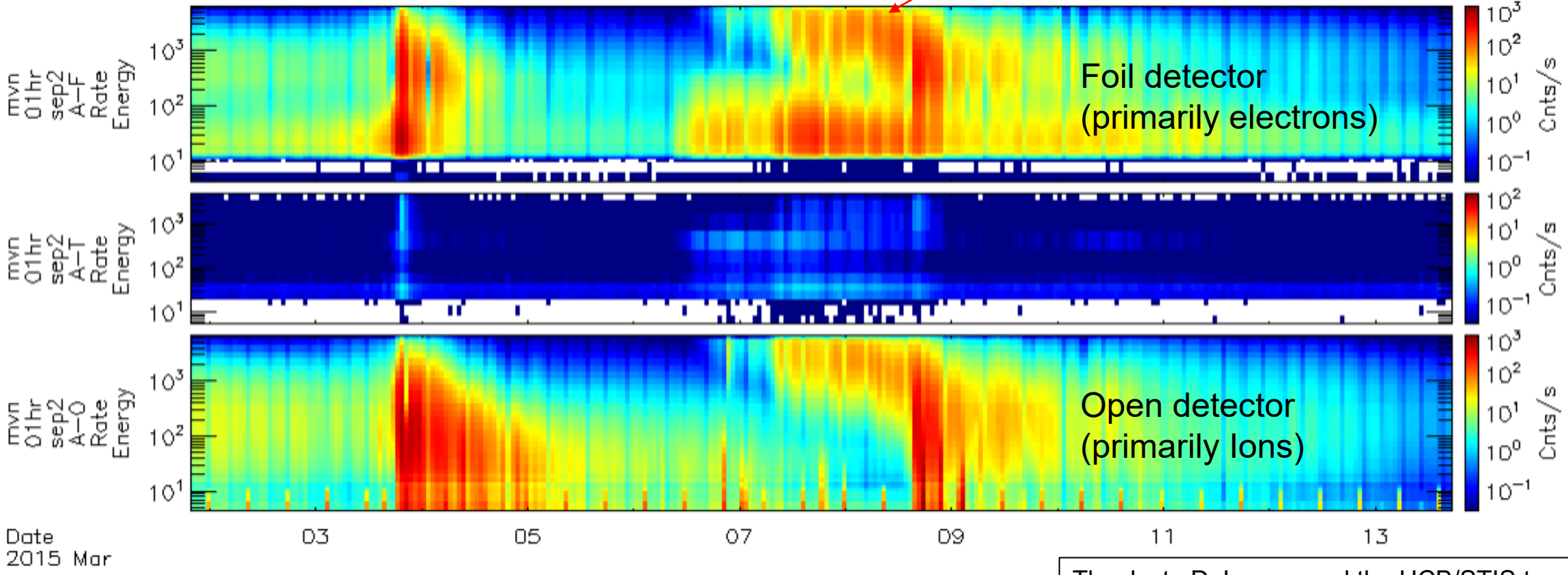
Thanks to A. Thernisien and the NRL/CCOR team

Cal/Val: STIS Energy–Count-rate Spectra

Measurements taken by MAVEN/SEP in orbit around Mars during March 2015

L1a data

Count-rates [counts s^{-1}] are derived directly from raw data [counts] by taking the sampling time into account

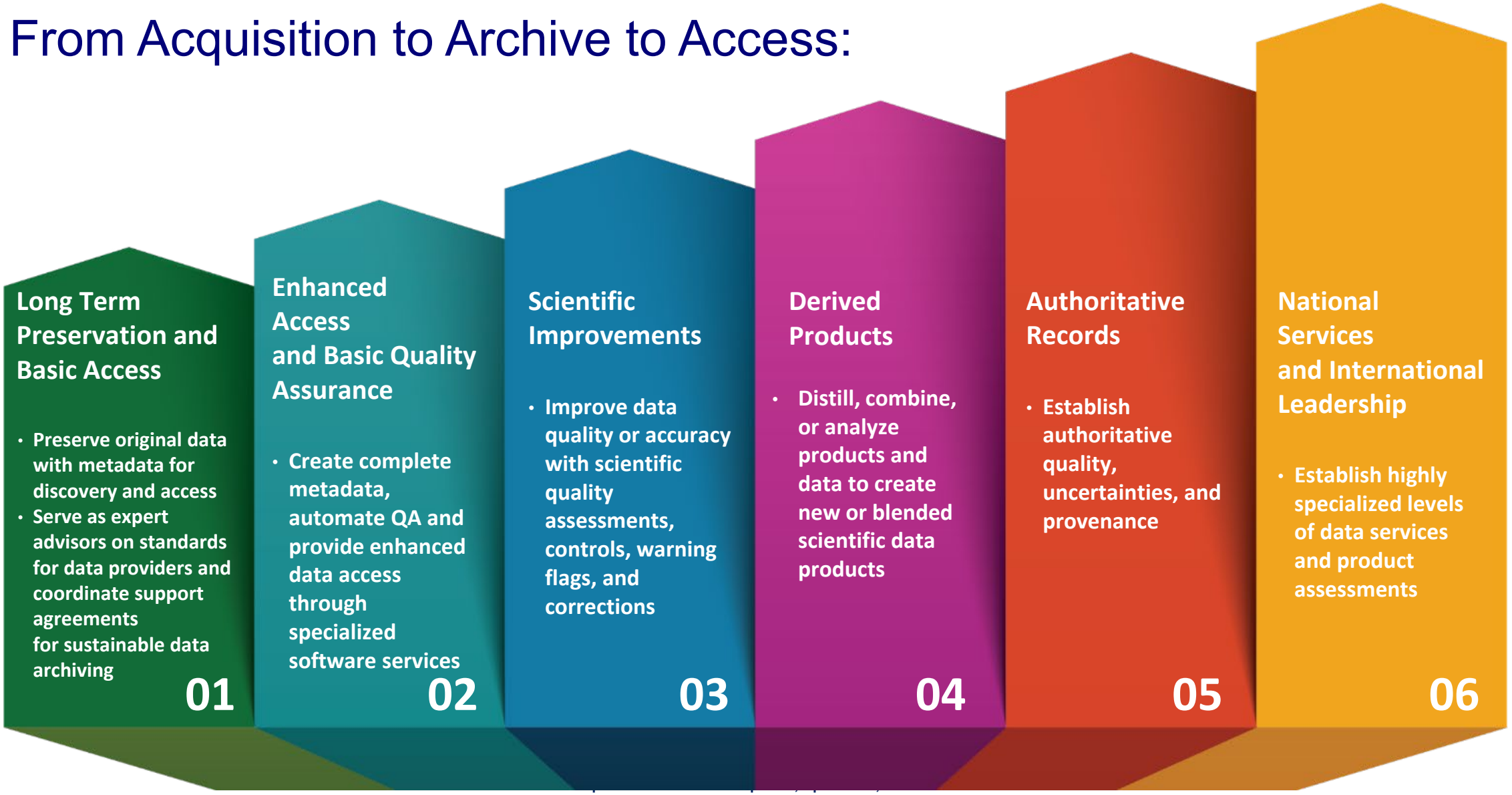


Thanks to D. Larson and the UCB/STIS team

C: SDD

NCEI: Tiers of Data Stewardship

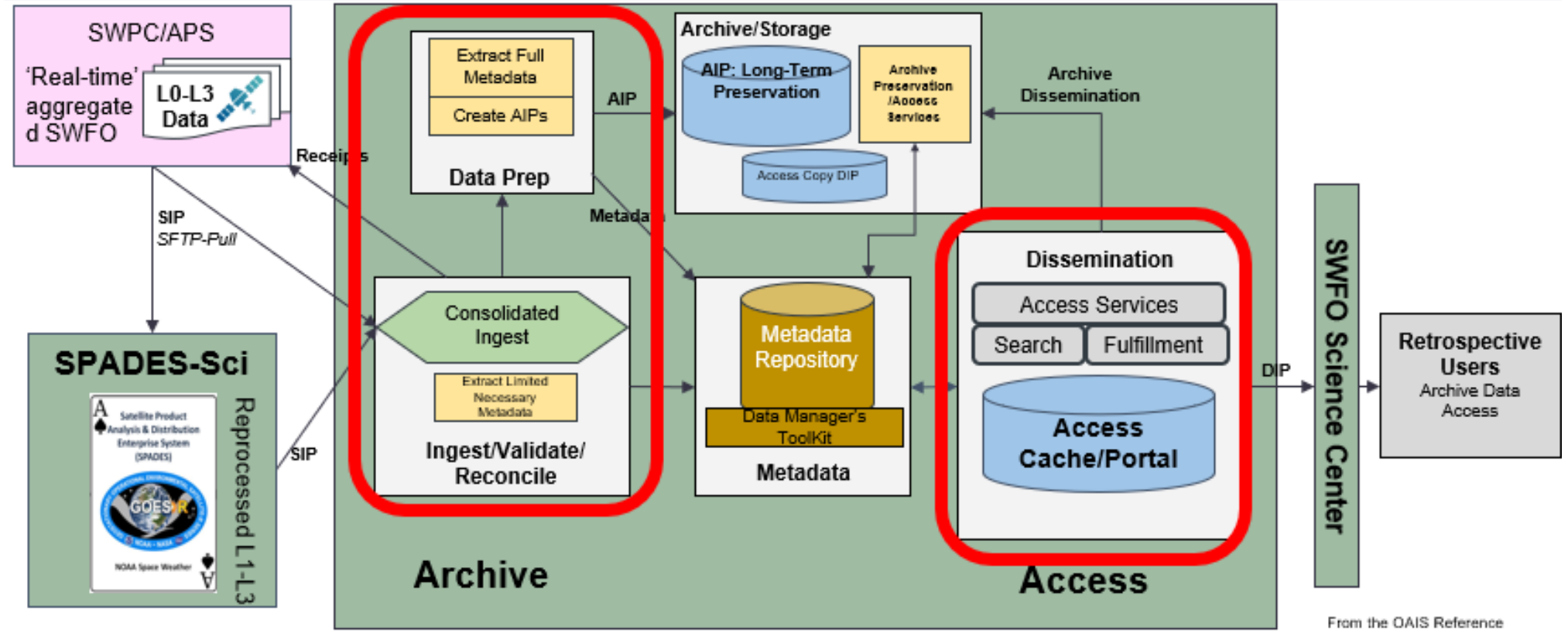
From Acquisition to Archive to Access:



Archiving in the NOAA Cloud

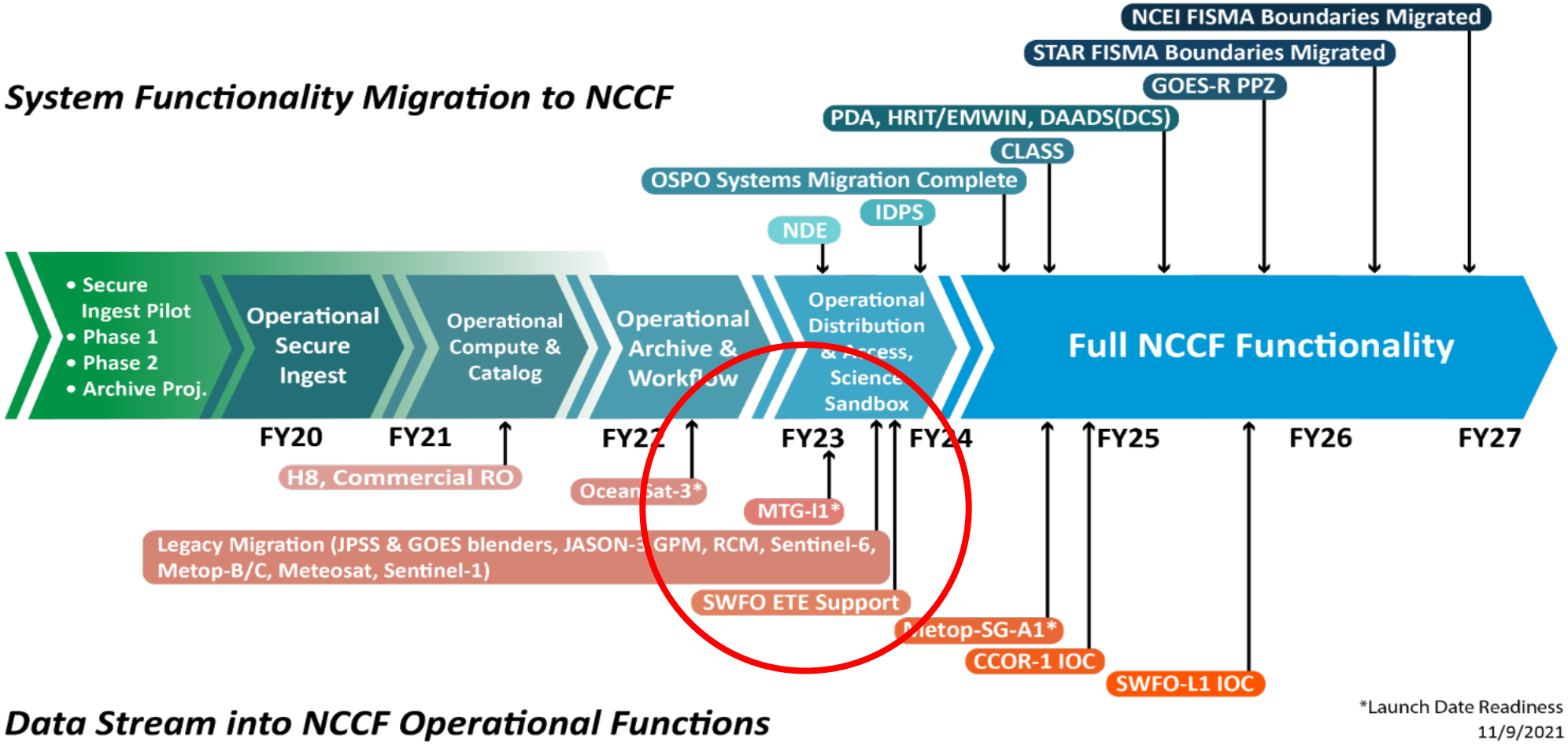
Coronal images and in situ data will be archived in the NOAA Common Cloud Framework (NCCF)

SWFO Archive Components



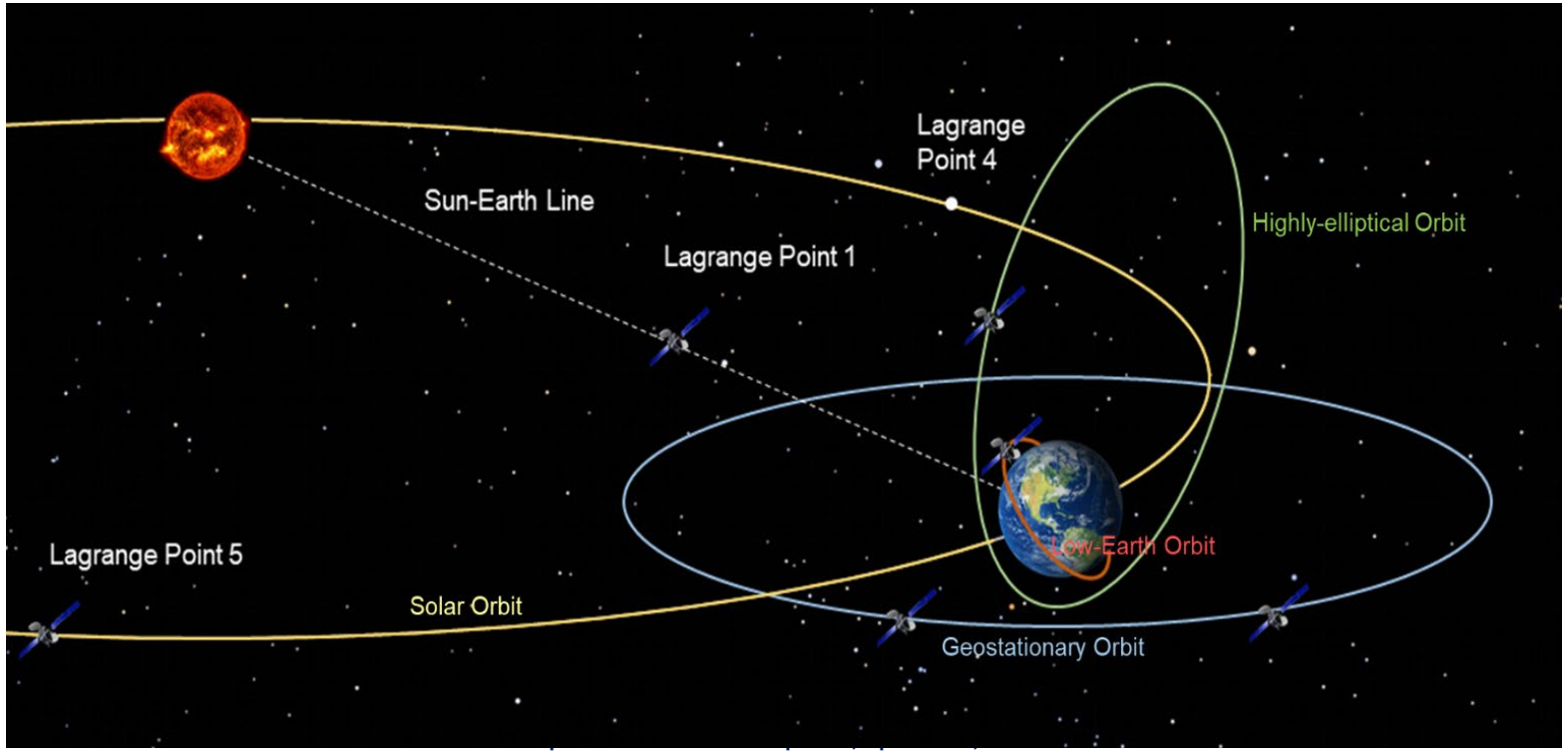
Timeline for Integration of SWFO data into the NOAA Cloud

Planned timeline:



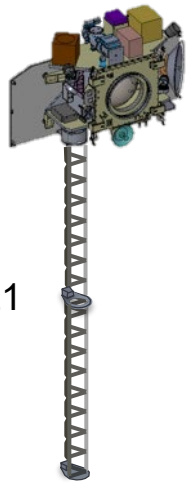
Next Steps

- SWFO has been developing ***User Readiness*** activities, such as this session, for its products. Web-based resources and meetings with users such as in community workshops are being considered.
- The SWFO Program is one of two major programs within NOAA/NESDIS/Space Weather Observations. It is setting a precedent for the more comprehensive ***Space Weather Next (SW Next) Program*** which is envisioned to provide solar, heliospheric, and other measurements in the late 2020s timeframe.



Backup

The SWFO Ground Segment

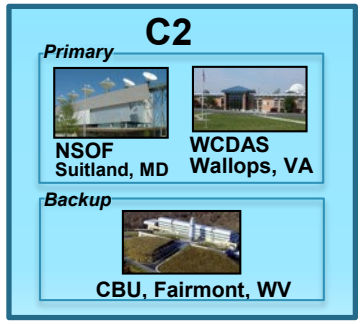


SWFO-L1

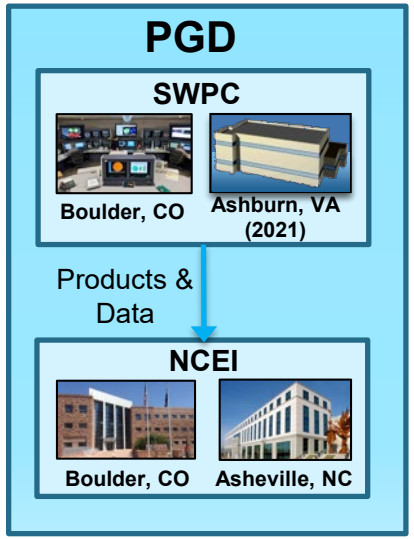
Via SAN element

The Ground Segment contains three elements.
Data are downlinked to the SWFO Antenna Network (SAN). The Command and Control (C2) element provides SWFO-L1 mission and housekeeping (HK) data to the Product Generation and Distribution (PGD) element. (*)
Within PGD:

- The Space Weather Prediction Center (SWPC) unit is responsible for processing and distributing products to operational users.
- The National Centers for Environmental Information (NCEI) unit is responsible for processing and making available all products to retrospective users.



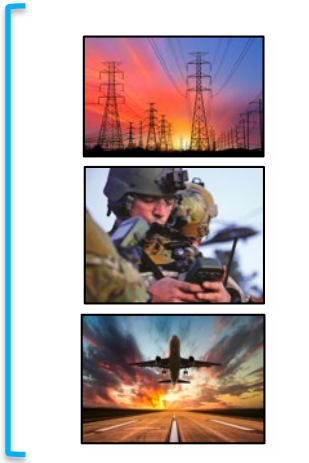
L0 Mission Data,
Hk Data,
Ancillary Data



Real-Time Products
to
Operational Users

All Products to
Retrospective
Users

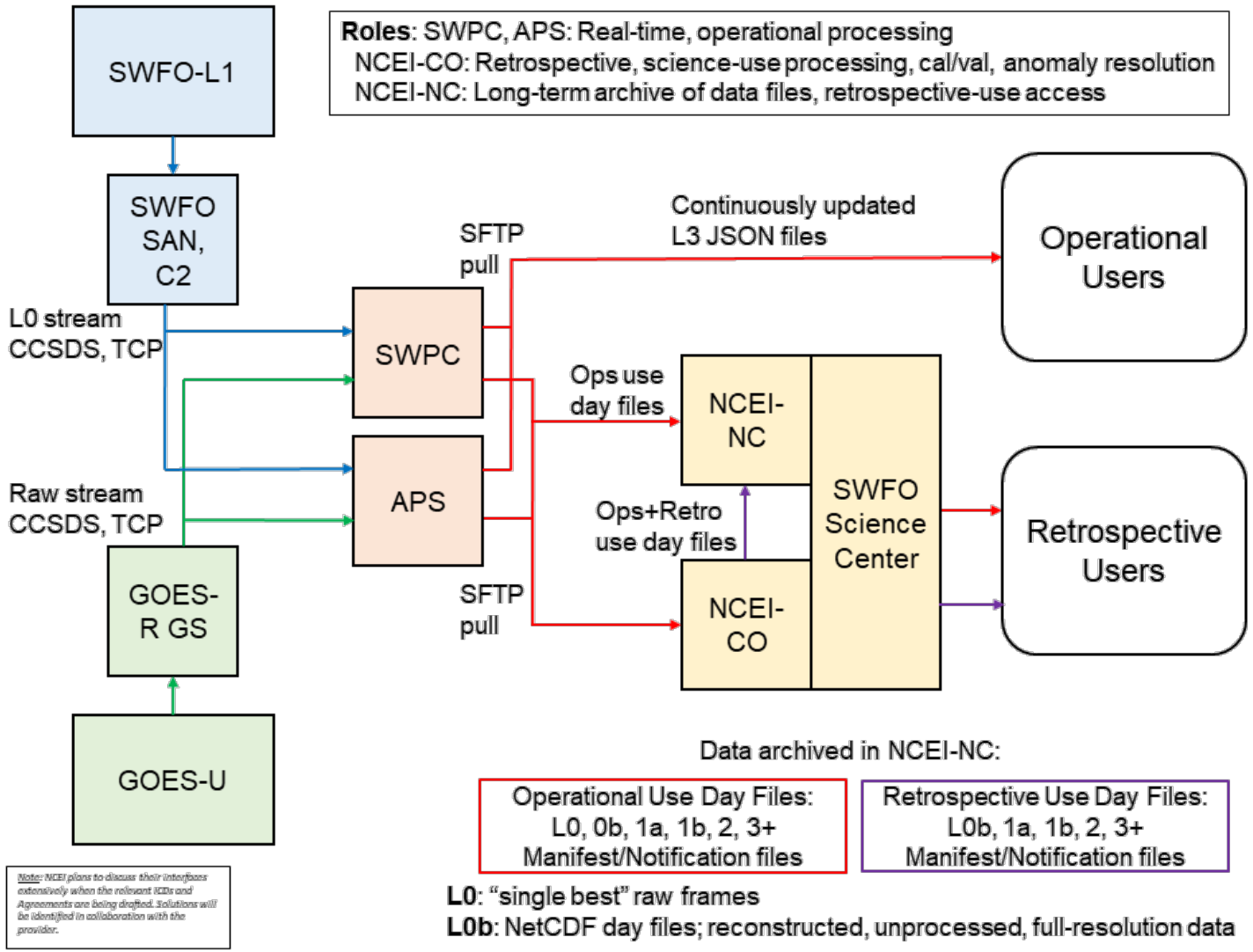
User Community



*In addition, SWPC receives GOES-U CCOR-1 data via the GOES-R Ground Segment (GS)

Data Processing: SWPC and NCEI

- **Product Generation**
  - Product generation for operational users takes place at NWS/SWPC (Boulder, CO) with a hot backup at the Alternate Processing Site (APS) on the East Coast.
  - Products for retrospective users are developed by NESDIS/NCEI.
- **Algorithm and Calibration Working Groups**
  - Include SWPC, NCEI, instrument developers, other Flight and Ground Segment teams.
- **Algorithm design and product development**
  - Takes place in a series of Git-based environment with information shared among the three types of developers (SWPC, NCEI, instrument teams)



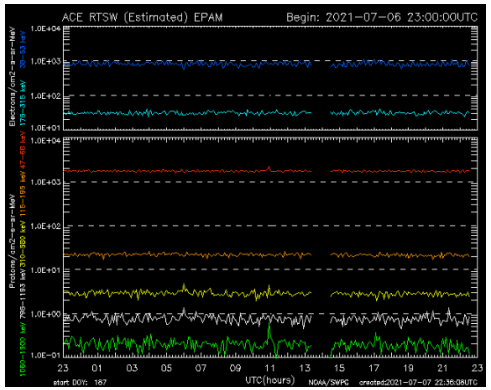
SWFO: Enabling Research (2/2)

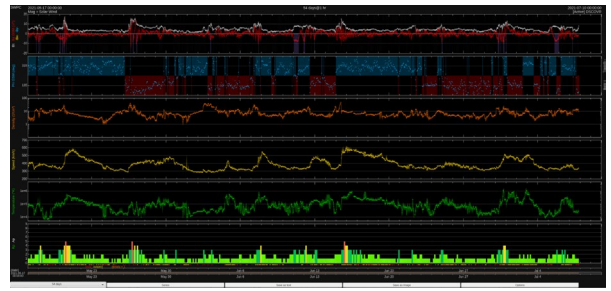
Questions from: "Nine Outstanding Questions of Solar Wind Physics" [Viall and Borovsky, JGR, June 2020]

Category	Question	SWFO Contributions
The formation of the solar wind	(1): From where on the Sun does the solar wind originate?	--
	(2): How is the solar wind released?	--
	(3): How is the solar wind accelerated?	--
Interpreting observations of solar wind parcels	(4): What determines the heavy-ion elemental abundances, the ionic charge states, and the alpha/proton density ratios in the solar wind? (And what do they tell us about the Sun?)	--
	(5): What is the origin and evolution of the mesoscale plasma and magnetic field structure of the solar wind?	✓
Physical mechanisms operating on solar wind formation and evolution	(6): What is the origin of the Alfvénic fluctuations in the solar wind?	✓
	(7): How is solar wind turbulence driven, what are its dynamics, and how is dissipated?	✓
	(8): How do the kinetic distribution functions of the solar wind evolve?	✓
	(9): What are the roles of solar wind structure and turbulence on the transport of energetic particles in the heliosphere?	✓

Products for SpWx Information Users

- **Data for operational users: SWPC**
  - SWPC will make available NRT data via NOAA's Web Operation Center (WOC)
  - All other files will be hosted for sftp access
  - SWPC will also provide QuickLook files to the instrument vendors. It will send L3 data and images to the Forecast Center. It will provide day files to NCEI for further processing and archiving.
  - The data will support SWPC's Alerts, Warnings, Watches, and other notifications which are accessible via a subscription service.





- **Data for operational users: NCEI**
  - NCEI is developing the SWFO Science Center, similar to the DSCOVR data portal (pictured on the right) and the GOES-R Space Weather site.
  - The Science Center's Application Programming Interface (API) will be designed to allow meta-portals such as the VSO (https://virtualsolar.org/) and CDAWeb (https://cdaweb.gsfc.nasa.gov/) to access SWFO data.