

# Polarimeter to Unify the Corona and Heliosphere

## NFI Instrument Status Overview

Robin Colaninno

NFI Instrument Lead

Distribution A. Approved for Public Release; Distribution Unlimited  
This work is supported by NASA



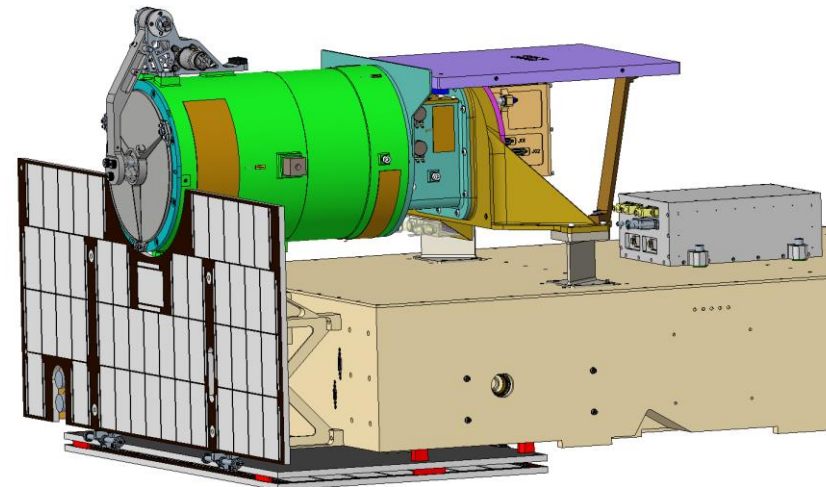
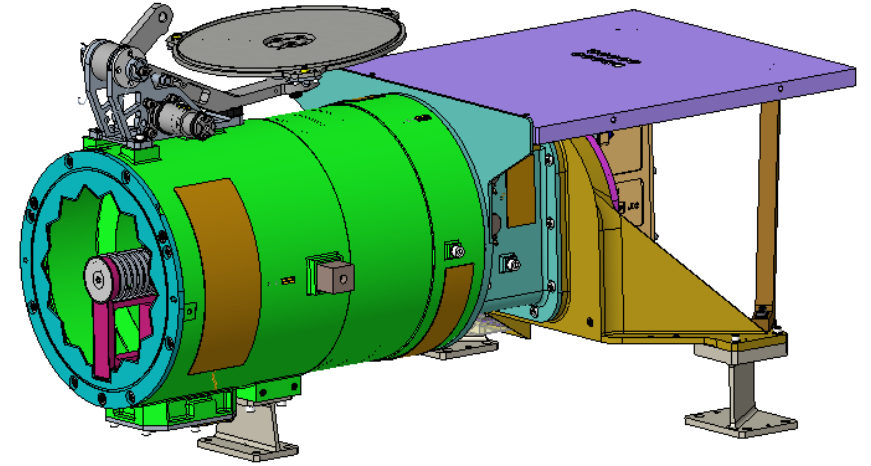
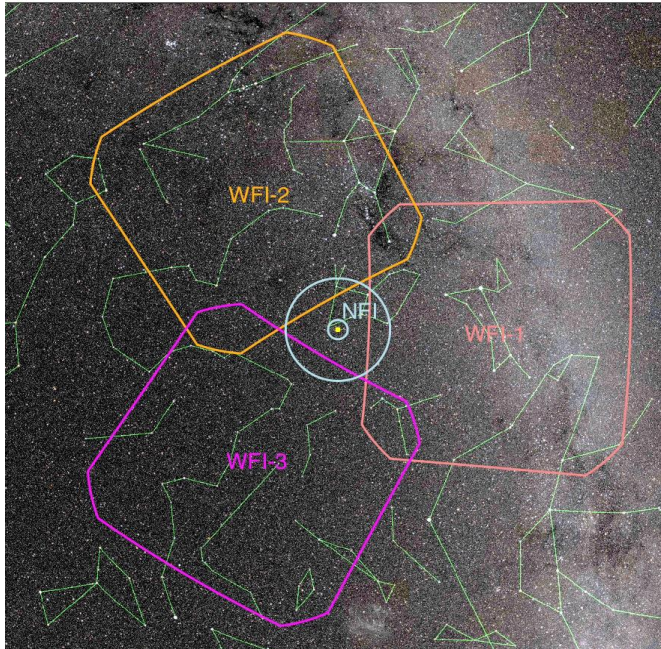
PUNCH 5 Science Meeting  
June 20-21, 2022  
Boulder, CO





# NFI Overview

- Combined NFI & WFI FOV provide first:
  - Wide-field, polarimetric, high resolution views of corona-solar wind transition
  - NFI:  $5.75 - 32 R_{\odot}$ , WFI:  $20-180 R_{\odot}$
- Provides high spatial/temporal resolution in the inner FOV
  - 1 observatory in polar orbit
  - Continuous 4 min observing cadence

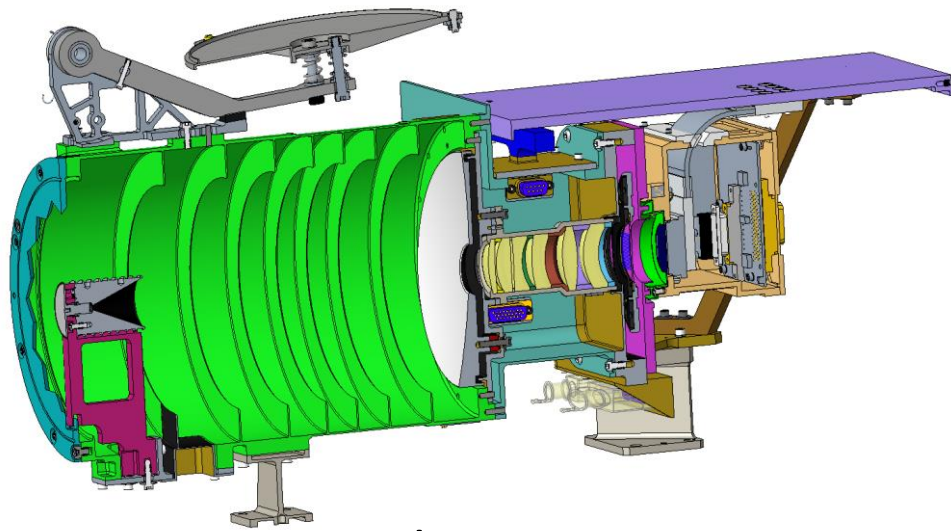
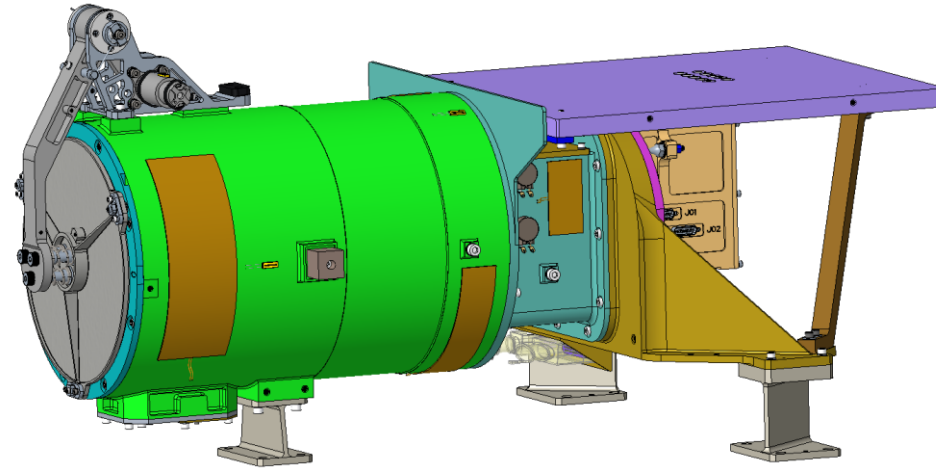




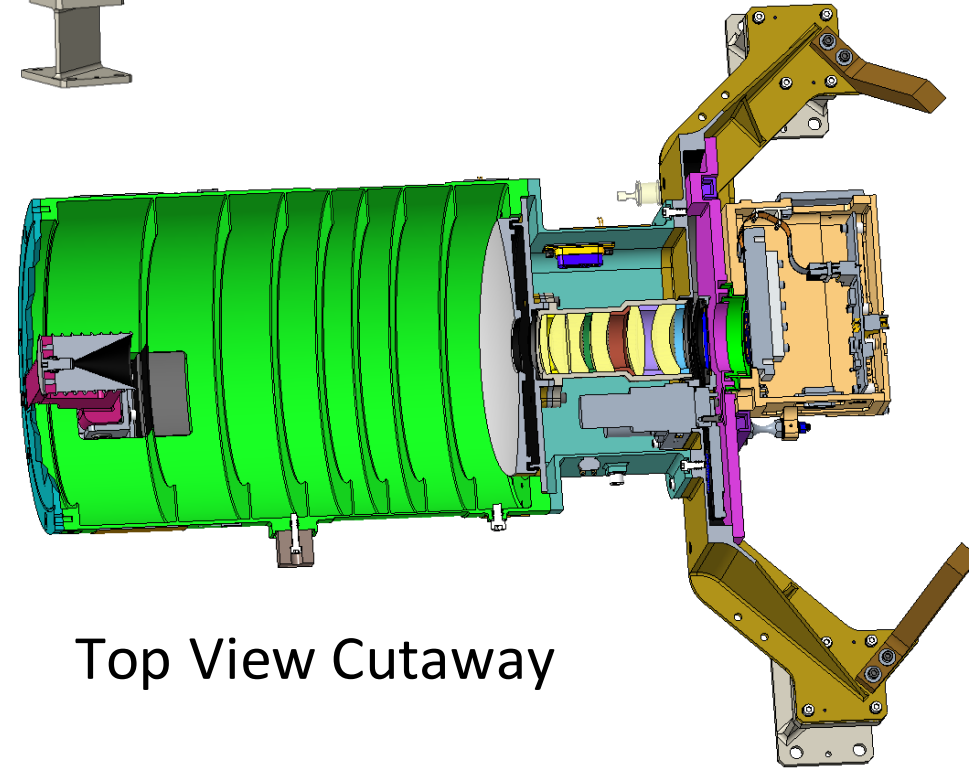


# NFI Instrument Layout

Side View



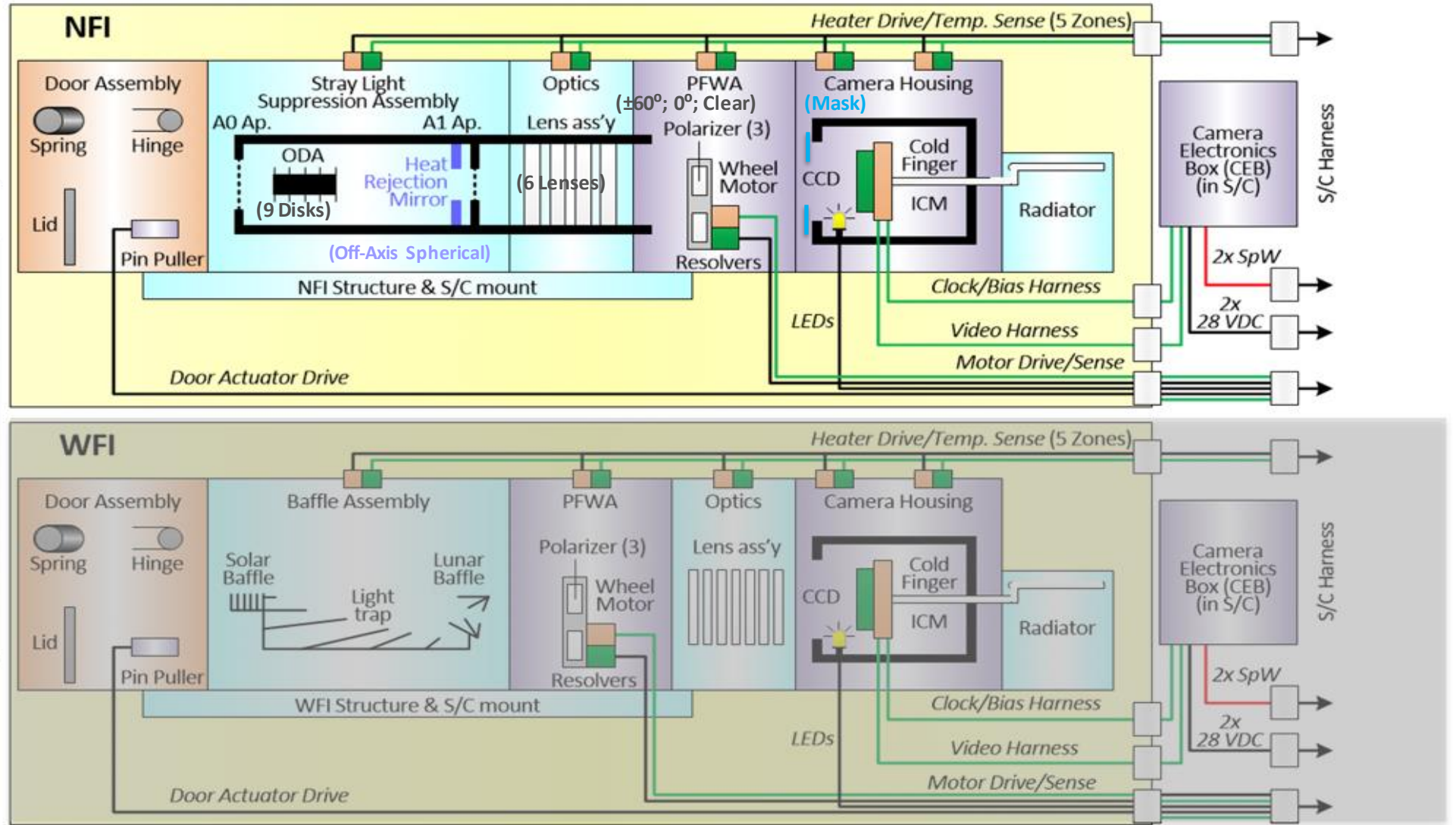
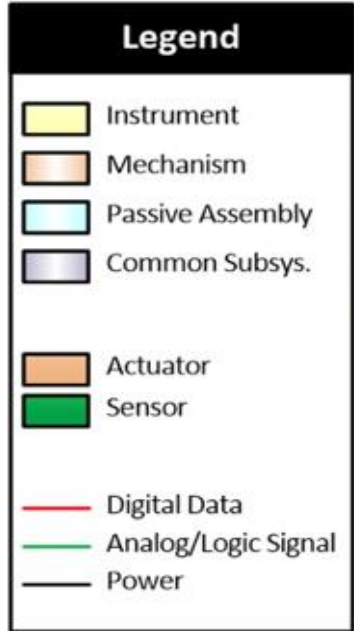
Side View Cutaway



Top View Cutaway



# NFI Physical Block Diagram

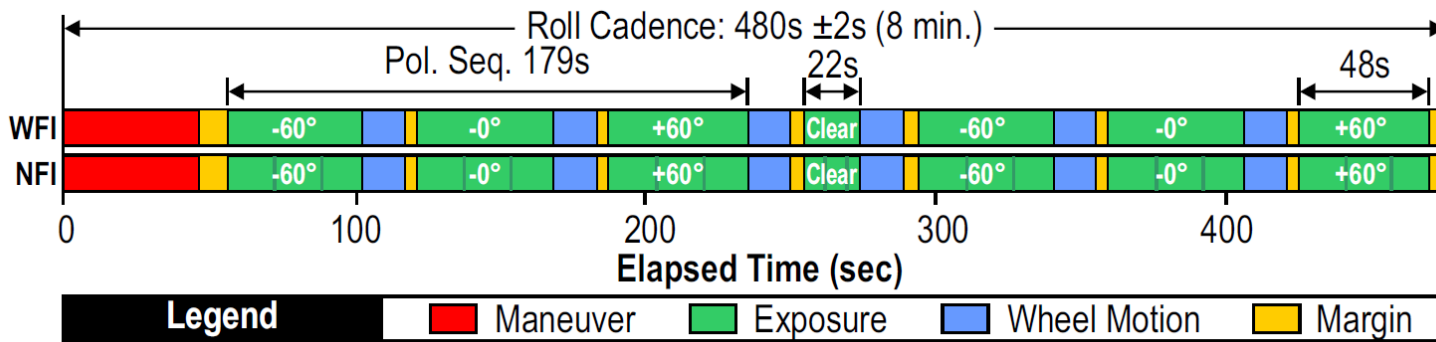






# NFI Observing Plan

- Conops common to WFI & NFI
- Two sets of polarization sequences per 8 min roll cadence
- Each image a summation of 3 exposures



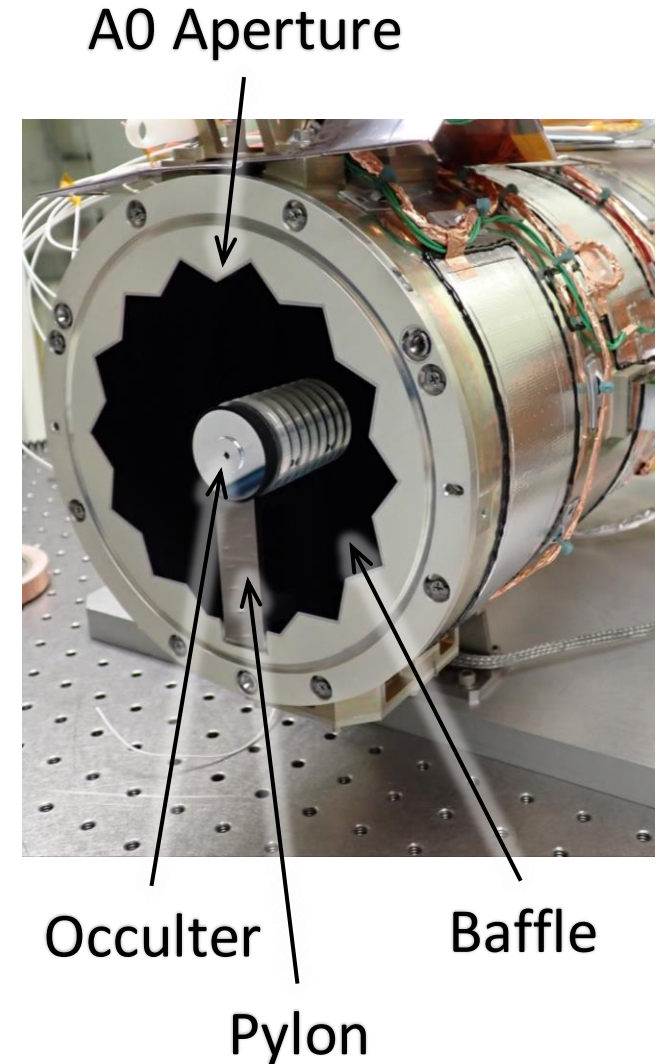
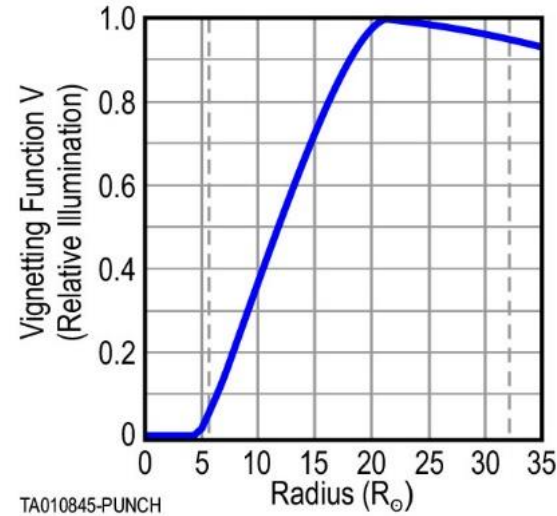
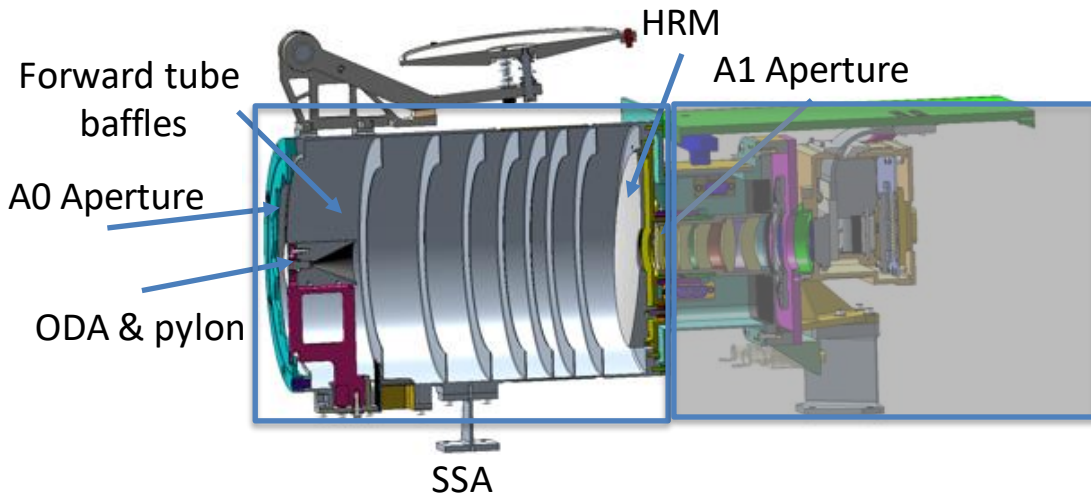
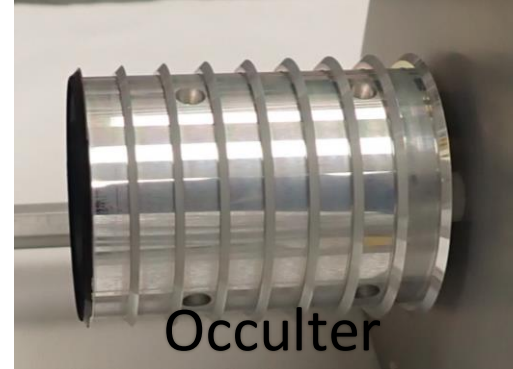
PUNCH Observing Sequence Schedule			
Time (s)	Length + margin	NFI Action	WFI Action
0	47+4	Roll & set PFW to $-60^\circ$	Roll & set PFW to $-60^\circ$
51	48+1(*)	Expose 3x13s at $-60^\circ$	Expose 45s at $-60^\circ$
98	15+5	Set PFW to $0^\circ$ & settle	Set PFW to $0^\circ$ & settle
118	48+1(*)	Expose 3x13s at $0^\circ$	Expose 45s at $0^\circ$
165	15+5	Set PFW to $60^\circ$ & settle	Set PFW to $60^\circ$ & settle
185	48+1(*)	Expose 3x13s at $60^\circ$	Expose 45s at $60^\circ$
232	15+5	Set PFW to CL & settle	Set PFW to CL & settle
252	22+1(*)	Expose 3x5s at CL	Expose 19s at CL
273	15+5	Set PFW to $-60^\circ$ & settle	Set PFW to $-60^\circ$ & settle
293	48+1(*)	Expose 3x13s at $-60^\circ$	Expose 45s at $-60^\circ$
340	15+5	Sep PFW to $0^\circ$ & settle	Sep PFW to $0^\circ$ & settle
360	48+1(*)	Expose 3x13s at $0^\circ$	Expose 45s at $0^\circ$
407	15+5	Set PFW to $60^\circ$ & settle	Set PFW to $60^\circ$ & settle
427	48+1(*)	Expose 3x13s at $60^\circ$	Expose 45s at $60^\circ$
474	1 to 11	Sync for next roll	Sync for next roll

(\*) 2-second overlap with following event



# NFI Stray-Light Suppression Assembly (SSA)

- SSA design has:
  - Occulter Disk Assembly (ODA) & pylon
  - Forward tube baffles
  - Front aperture A0
  - Heat Rejection Mirror (HRM)
  - Entrance aperture A1
- Vignetting from the ODA ends at  $21.9 R_{\odot}$ 
  - Optimized for the coronal brightness gradient and overlap with the WFI FOV

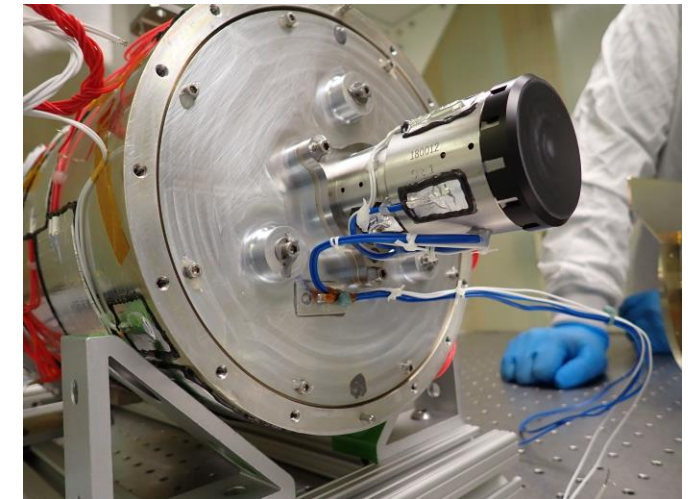
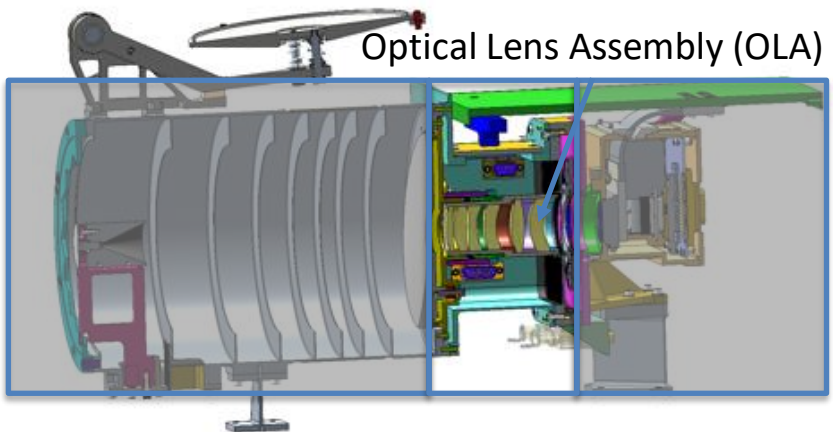
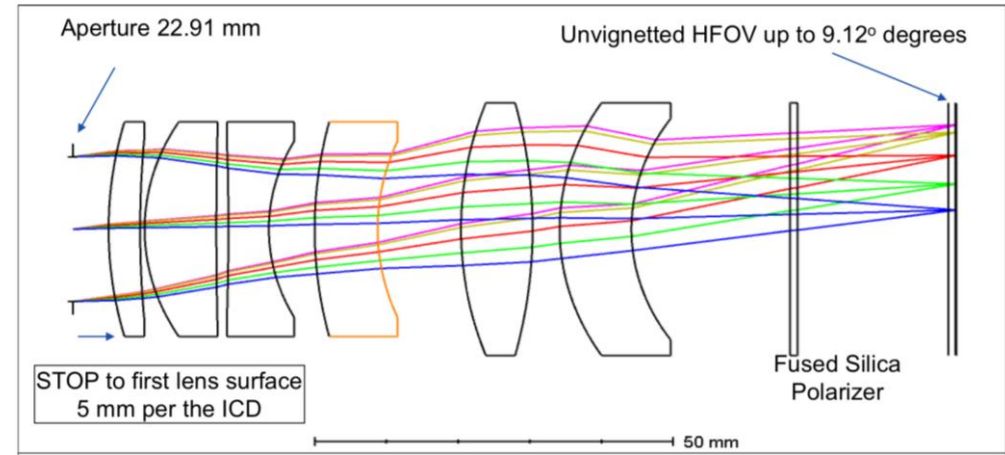






# NFI Optical Lens Assembly (OLA)

- NRL developed design
  - Six optical elements
  - Achromaticity between 450-750nm
  - >85% throughput, includes bandpass filters
  - F/4.5 lens
  - Plate scale 30"/15  $\mu\text{m}$  pixel.



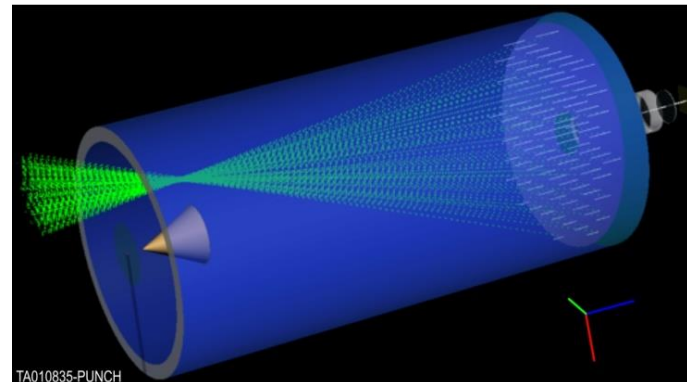
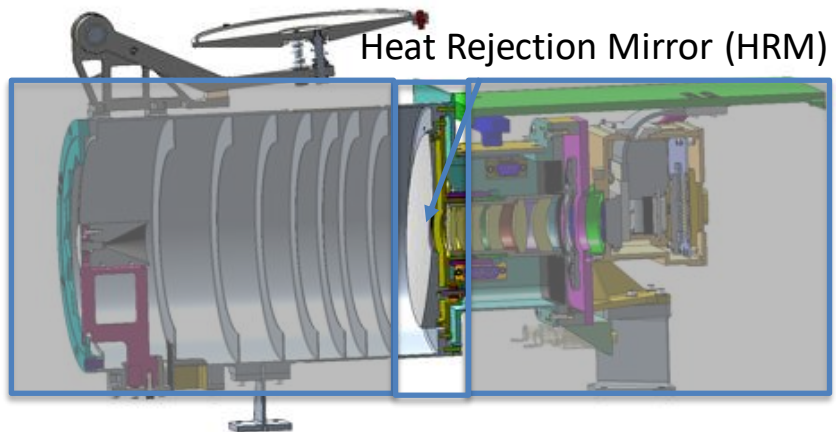
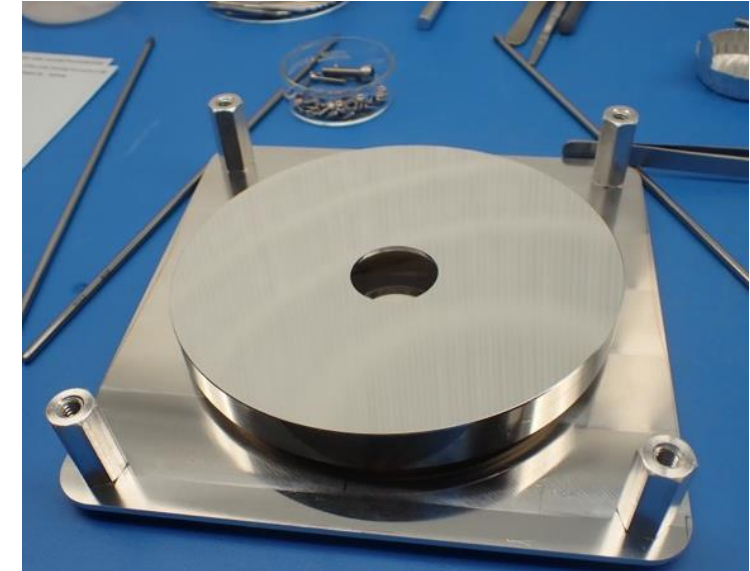
Lens assembly integrated onto the baffle and A1 bulkhead.



# NFI Heat Rejection Mirror

- Minimizes scattered light in SSA and heating of instrument
  - Off-centered, parabolic mirror
  - 255-mm focal length
  - Creates an image of the Sun opposite the occulter pylon
  - Scatter due to surface imperfections  $8.8 \times 10^{-12}$  CBE+C

HRM



HRM Focal Point

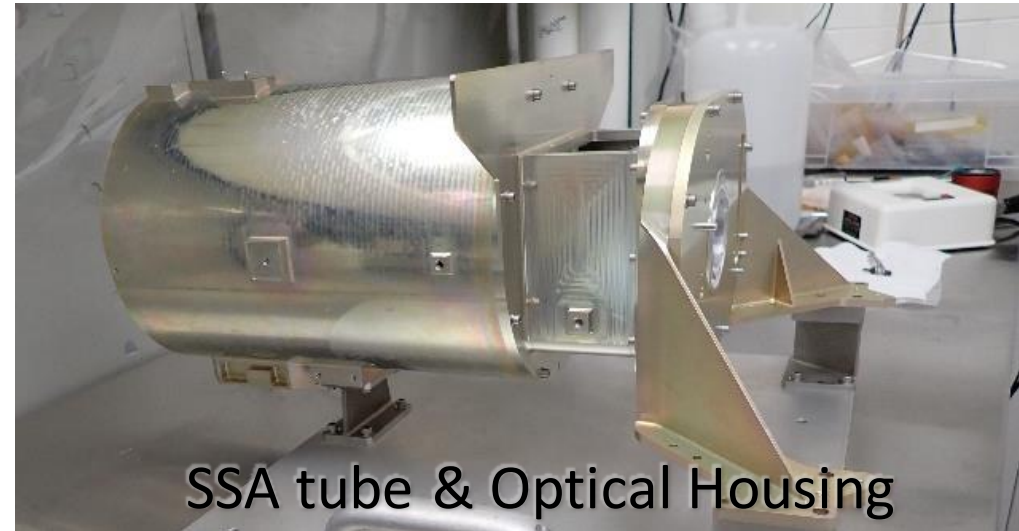
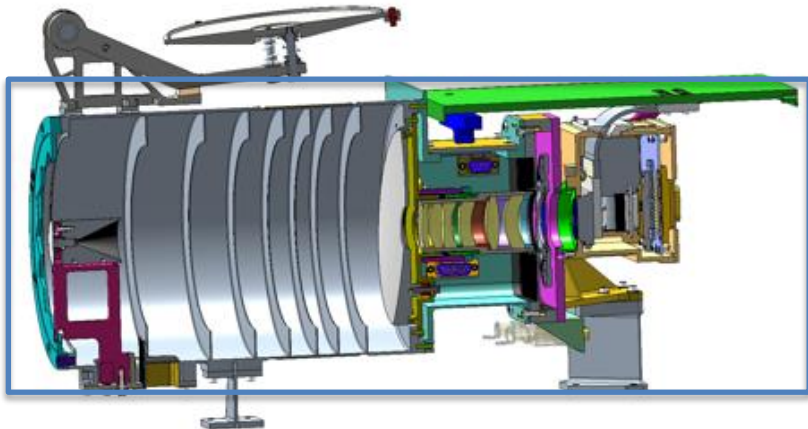
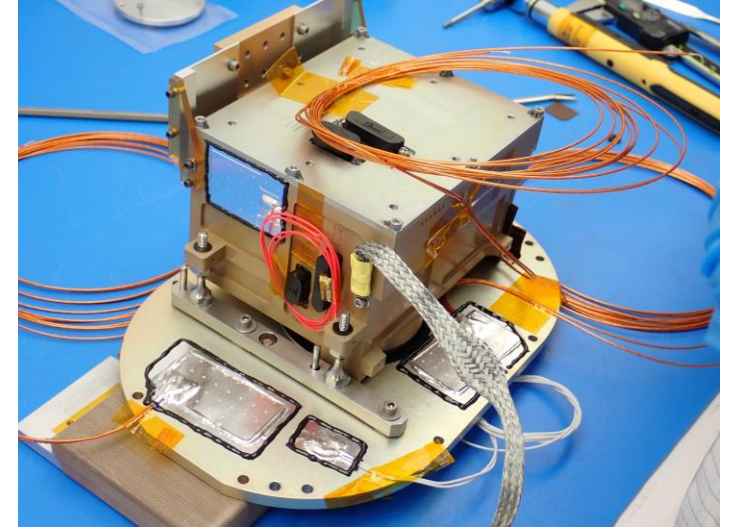




# NFI Structure

- Aluminum tube construction
- Three piece design
  - SSA tube, optical housing, camera box
- Alignment determined by shims at the interfaces
- NFI Structure mounts to S/C via 3-point Ti kinematic mount
  - Thermally isolated from S/C
  - Provides alignment with S/C

FM camera box



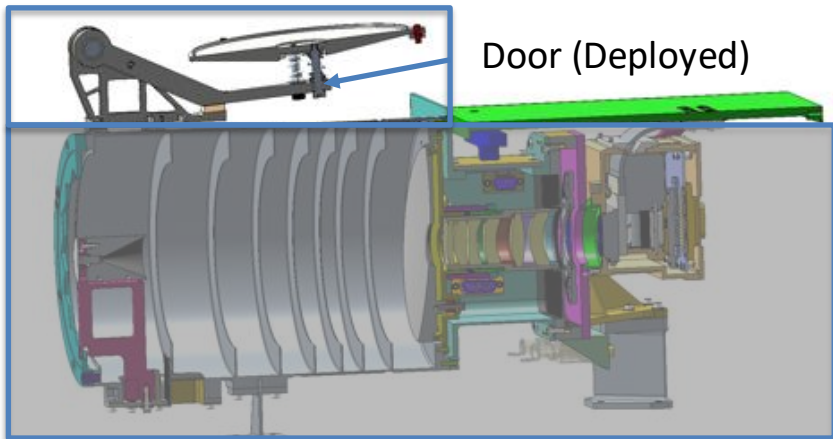
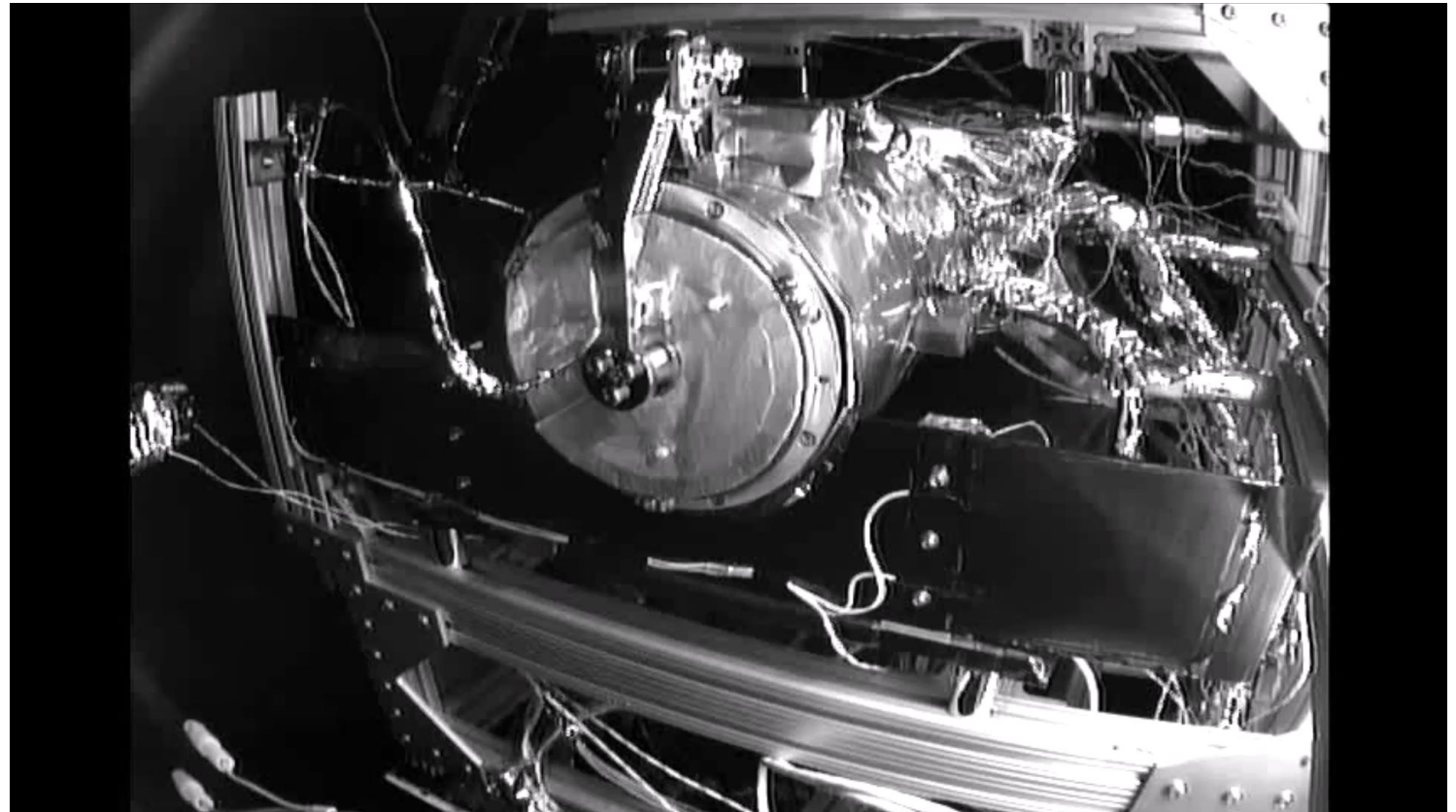
SSA tube & Optical Housing



# NFI Door

- Single one-time-open door
  - Provides contamination protection during S/C I&T, launch and early operations
  - All elements behind A0 for clear 180° field of regard
- Paraffin Wax Resettable Pin-Puller
  - Common to NFI and WFI

## Door Integration Test

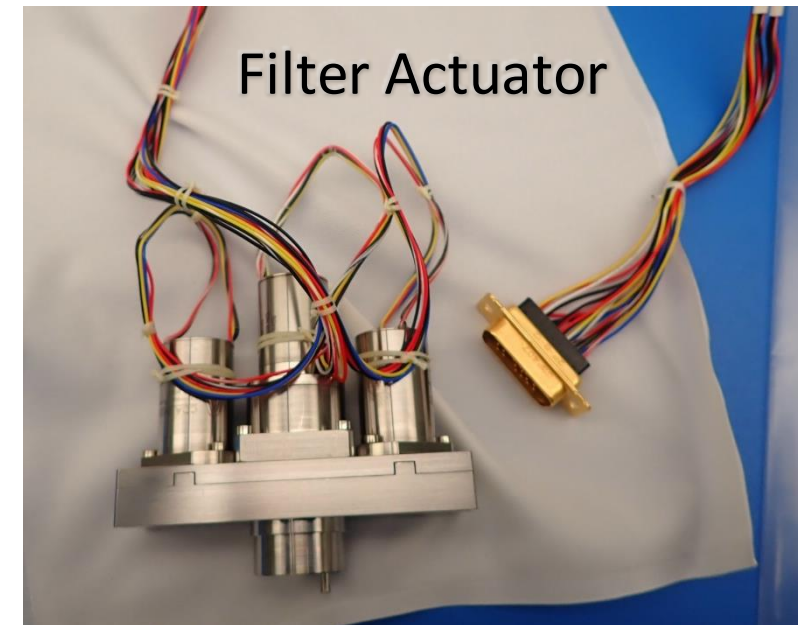
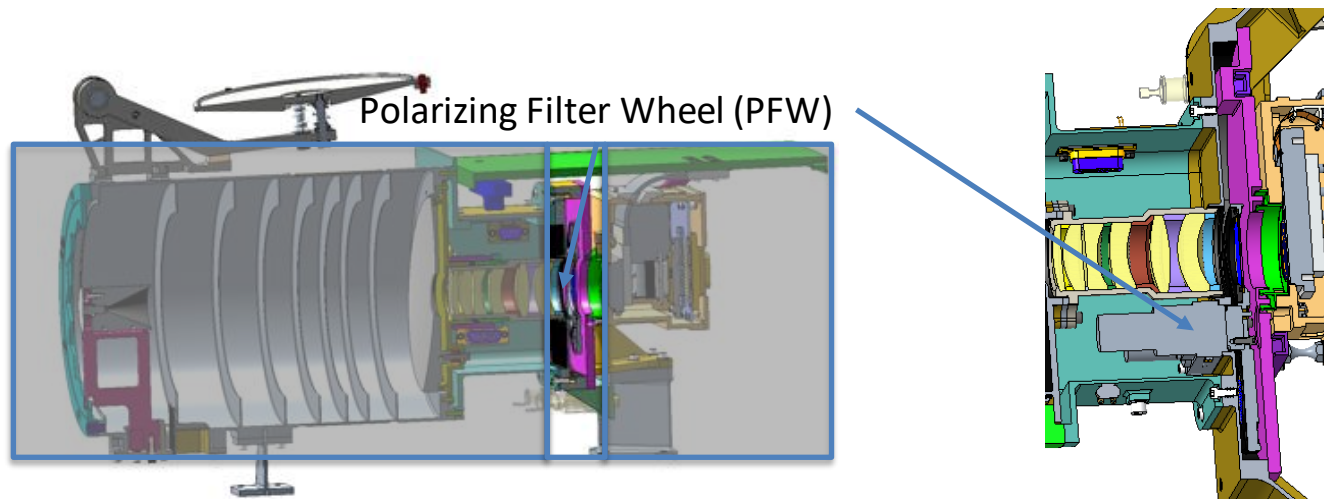






# Polarizing Filter Wheel (PFW)

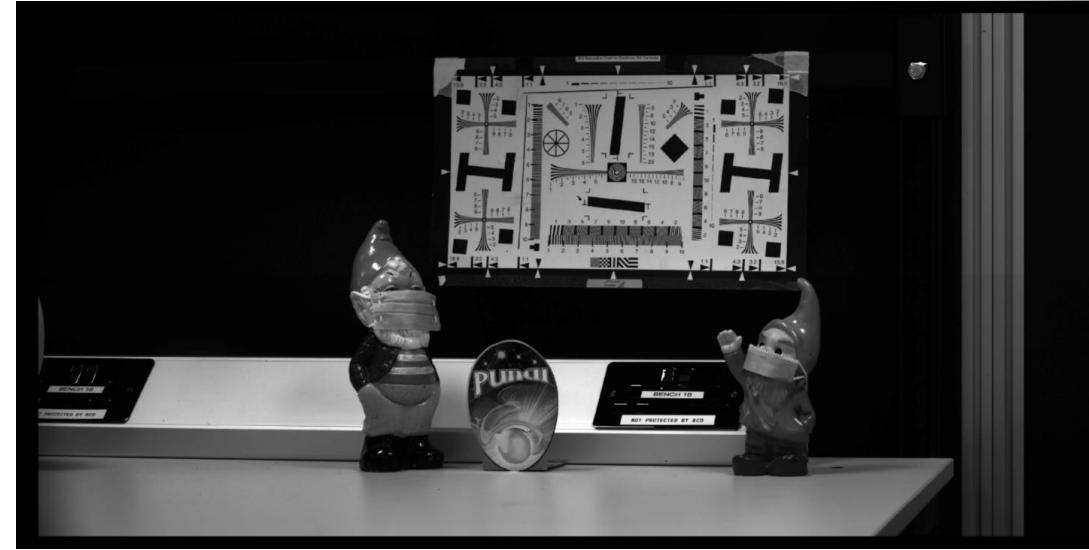
- PFW is common to WFI & NFI
- Provided by NRL to NFI & WFI
- 5-position filter wheel
  - Filters:  $-60^\circ$ ,  $0^\circ$ ,  $+60^\circ$  linear polarizers
  - Clear glass (optical focus consistency)
  - Blank (for Safing, Stim LED lamp)
- Linear Polarizers
  - Al nanowire lithographically applied to glass
  - Superior contrast ratio ( $>1000:1$ ) and transmittance ( $>85\%$ )



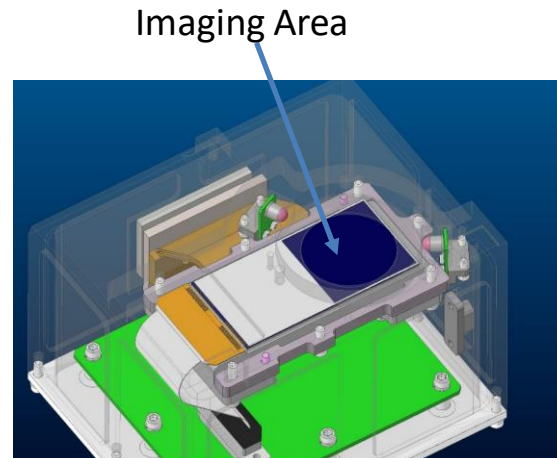
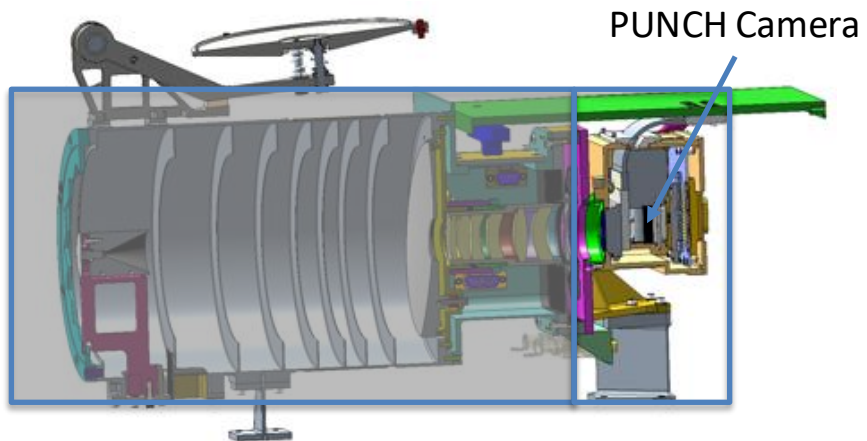


# PUNCH Camera

- Camera system identical in WFI & NFI
- Build by RAL, STEREO Heritage
- Teledyne-E2V CCD
  - 2k x 2k Imaging Area
  - 2k x 4k pseudo-charge-transfer CCD



PUNCH EM CCD - full-frame readout with frame-transfer storage area 4200 x 2148 pixels



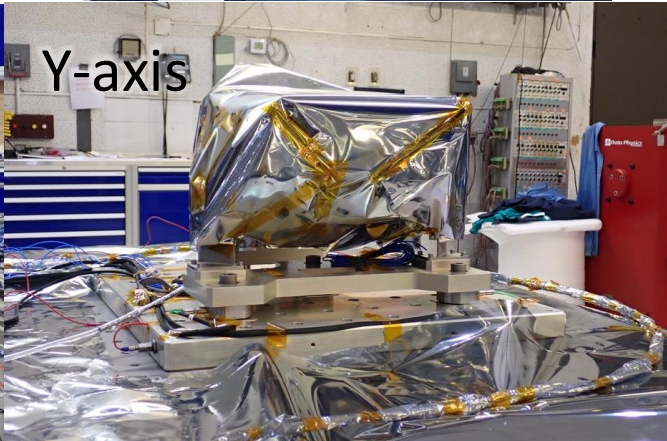
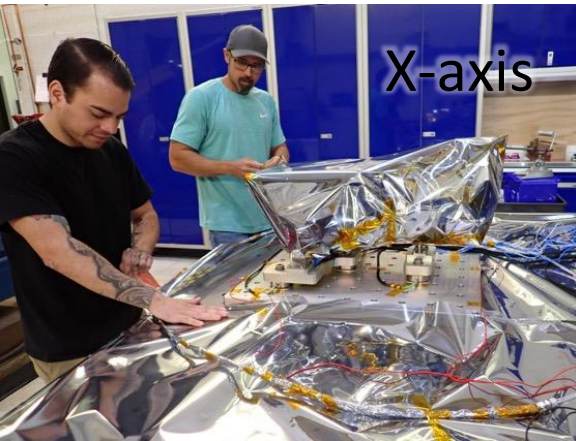




# Environmental Testing

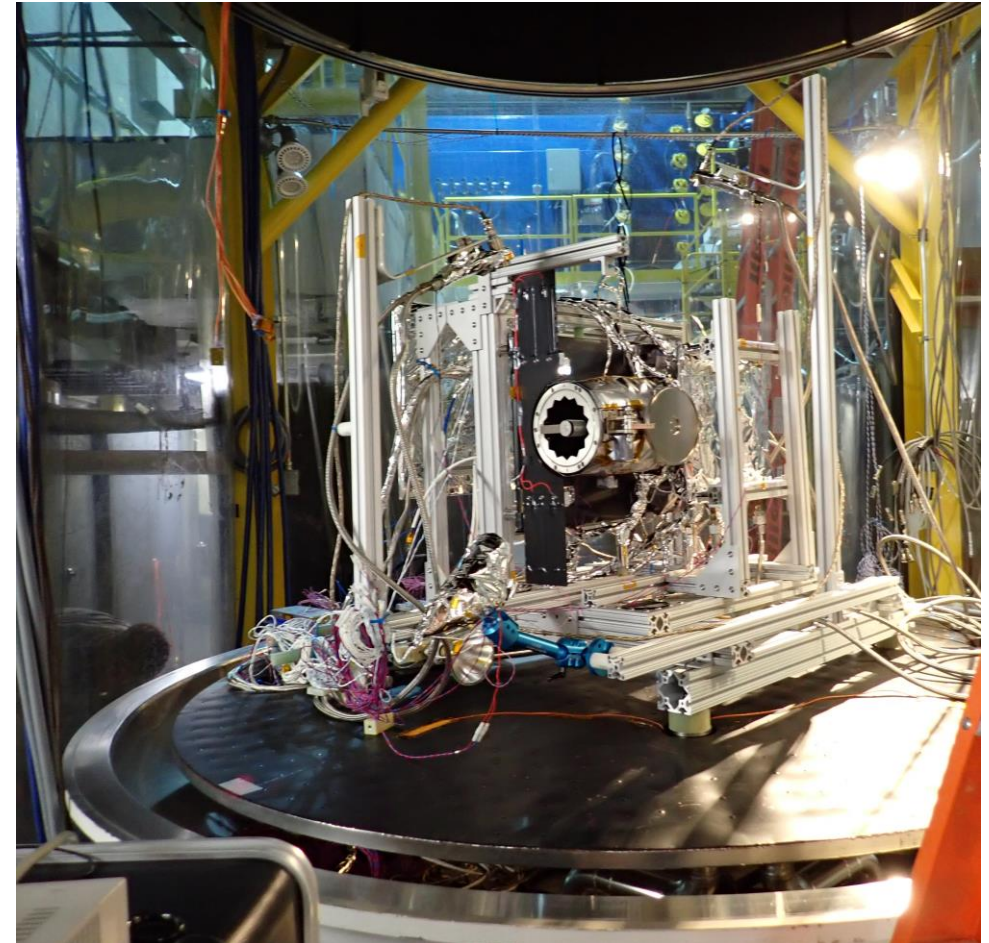
- Vibration Testing

- Simulates vibrations seen at launch
- Each axis of the instrument is tested independently



- Thermal Vacuum Testing

- Simulates the temperatures seen on-orbit in vacuum

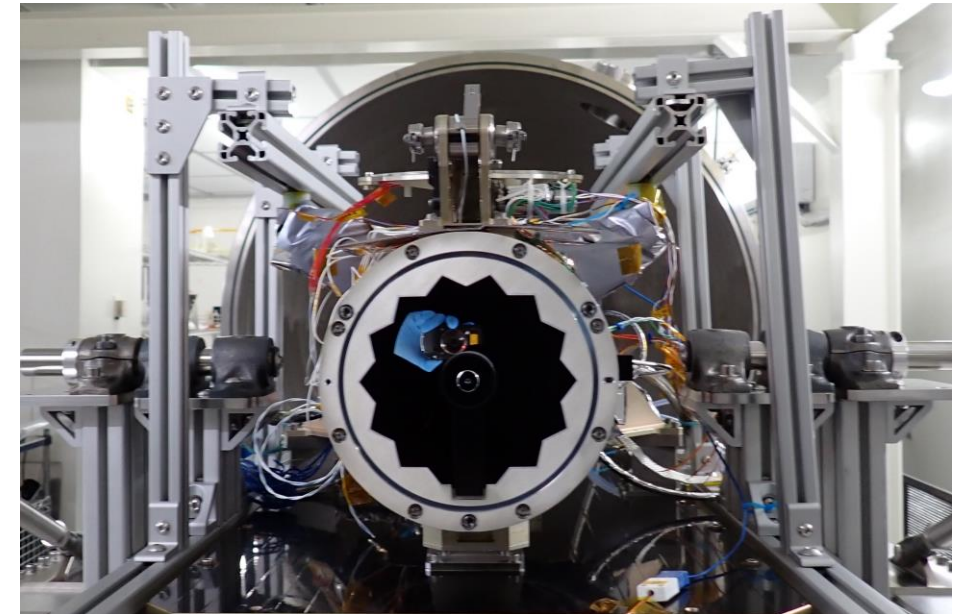
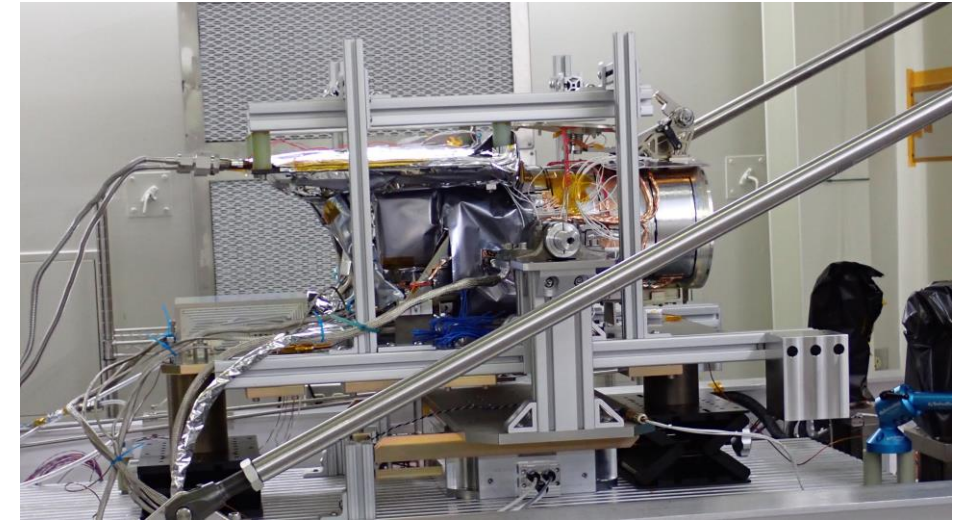






# Pre- & Post-Environmental Testing: SCOTCH Testing

- Optical Testing of Complete instrument
  - In vacuum at operational temperatures
  - Solar simulator provides collimated light







# Instrument Delivery SwRI San Antonio

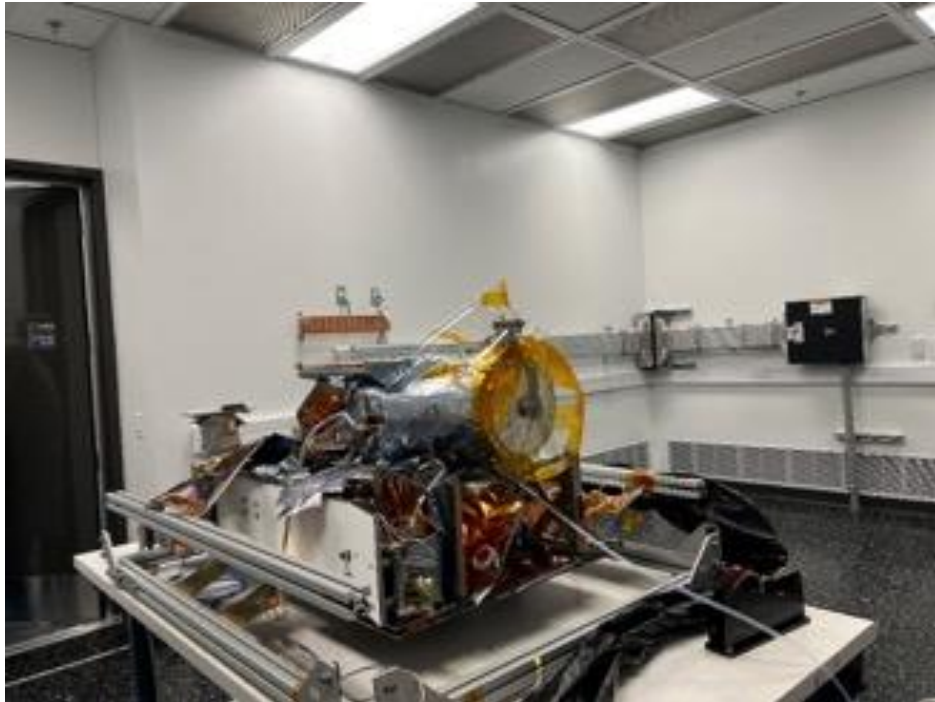






# NFI Spacecraft Integration

- NFI was integrated onto a PUNCH Spacecraft
- PUNCH-NFI-Spacecraft successfully completed Vibration, Shock and Acoustic testing
- PUNCH-NFI-Spacecraft is in Thermal Vacuum (TVAC) testing



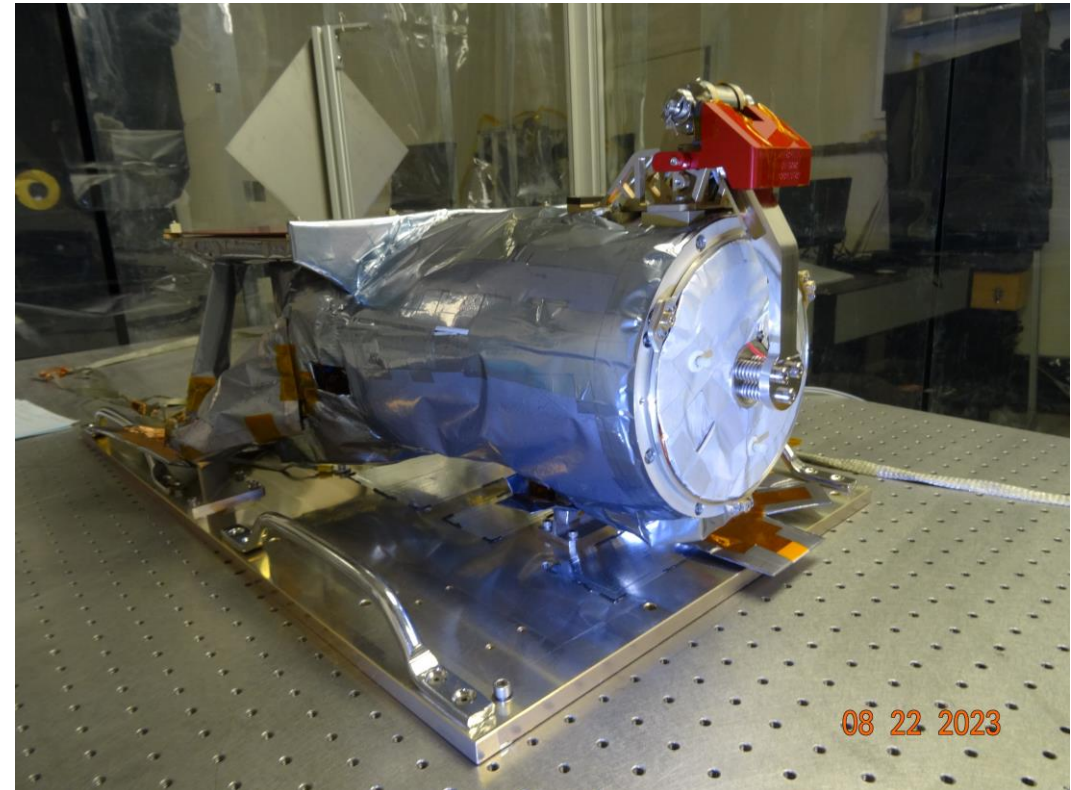




# Summary

- NFI design meets driving requirements and Science Objectives
- NFI was successfully delivered to the PUNCH mission for Spacecraft integration and environmental testing
- NFI is currently in Spacecraft TVAC

GO NFI  
GO PUNCH



# Polarimeter to Unify the Corona and Heliosphere



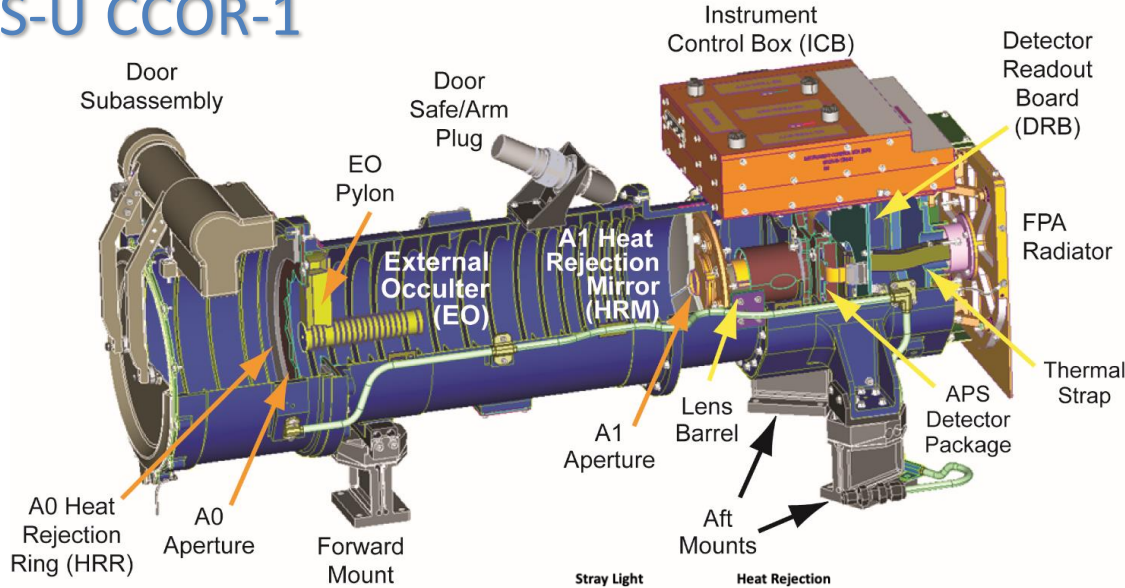
Backups



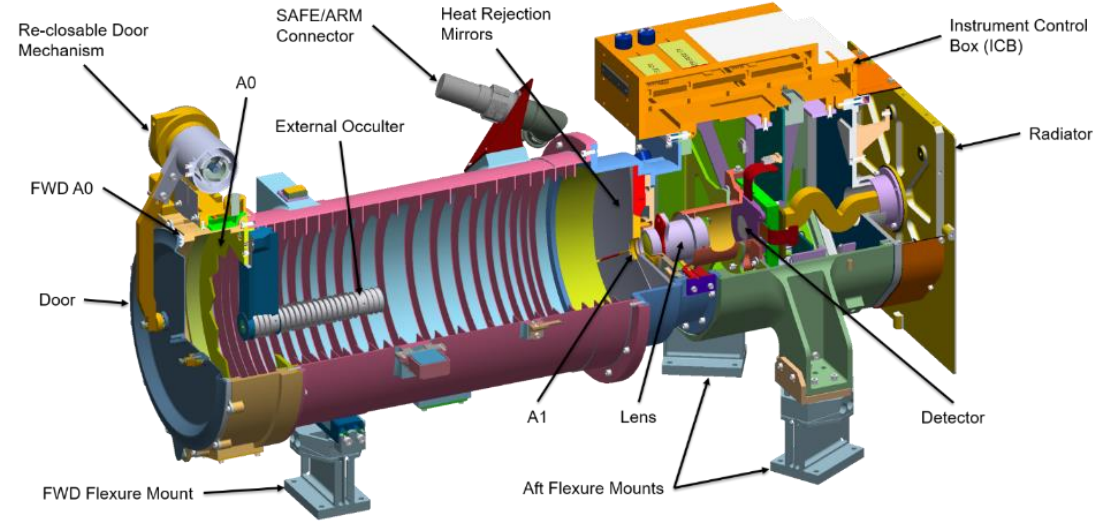


# Instrument Layout

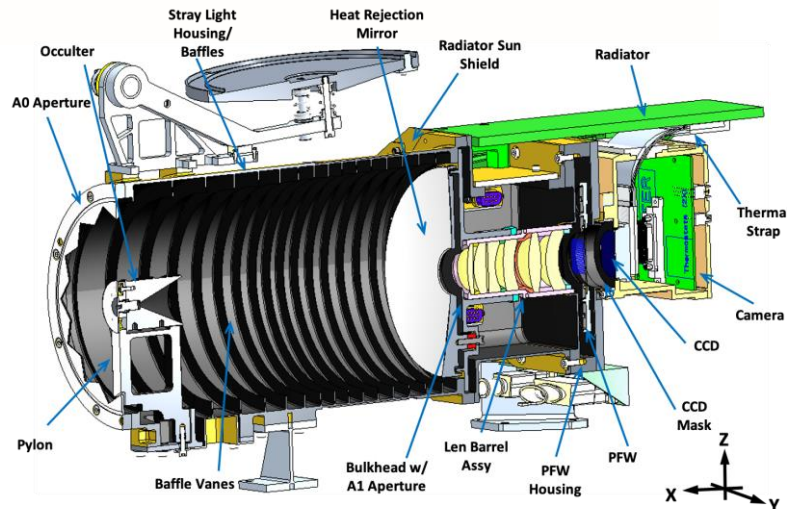
## GOES-U CCOR-1



## SWFO CCOR-2



## PUNCH NFI



## ESA vigil CCOR-3





# Project Overview

	PUNCH NFI	GOES-U CCOR-1	SWFO CCOR-2	vigil CCOR-3
Mission	NASA PUNCH	NOAA GOES Program	NOAA SWFO-L1	ESA vigil
Classification	Class D	Tailored Class C	Tailored Class C	--
Focus	Research/Science	Operations	Operations	Operations
Phase	Start of Integration	S/C Environmental Testing	Integration	Development
LV	Falcon 9 - SPHEREx ride share	Falcon Heavy	Falcon 9 Full Thrust - IMAP ride share	--
Orbit	LEO 6am/6pm	Geosynchronous	Lagrange 1	Lagrange 5
Lifetime	2 years	15 years	5 years	--
FOV	6 - 32 R <sub>☉</sub>	3.5 – 17 R <sub>☉</sub>	3.0 – 22.0 R <sub>☉</sub>	3.0 – 22.0 R <sub>☉</sub>
Detector	RAL provided CCD	NRL APS	NRL APS	NRL APS
C&DH/FSW	SwRI provided	NRL provided	NRL provided	NRL provided
Data Resiliency	50%	100%	100%	--
Cadence	8 min	12 minutes	12 minutes	--
Data Latency	12 hours (SSC-US)	15 minutes	15 minutes	--