

Polarimeter to Unify the Corona and Heliosphere



PUNCH 4 Science Meeting
July 6-7, 2023
Boulder, CO

WFI Instrument Status

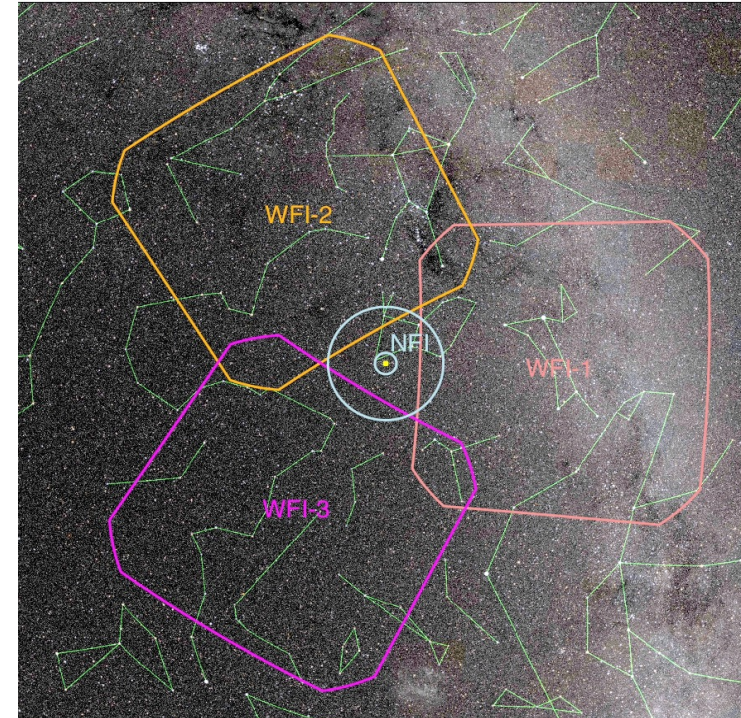
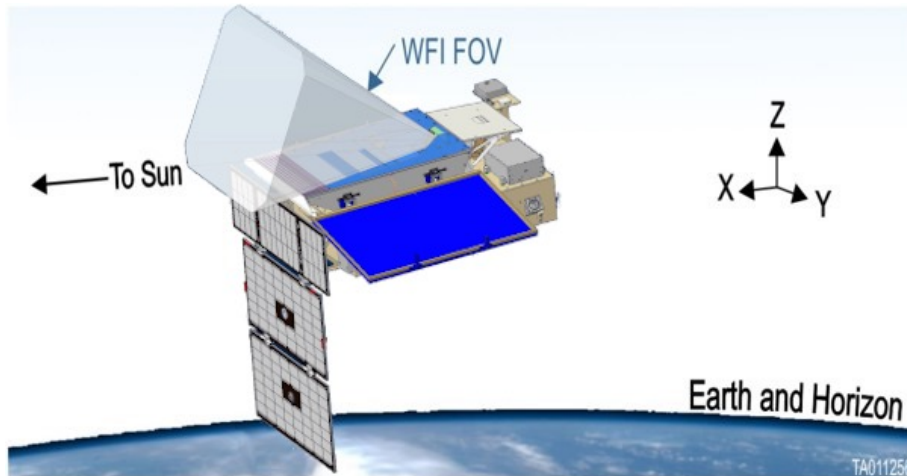
Glenn Laurent
WFI Instrument Lead





WFI Overview

- WFI/NFI provide first complete, photometric, high resolution views of corona/solar wind transition.
 - WFI 5-45°, NFI 1.4-8°
- WFI provides first wide-field polarimetric solar wind images.
- Design based on STEREO/HI, SoloHI - heliospheric imagers.
- 3 observatories in 620 km polar orbit (95.95 min)
- Rotating trefoil pattern orbit separated by 120° ± 30°.
 - Continuous observations 4 min observing cadence (2x per roll)
 - Full coverage in 32 min
 - 30° roll every 8 min

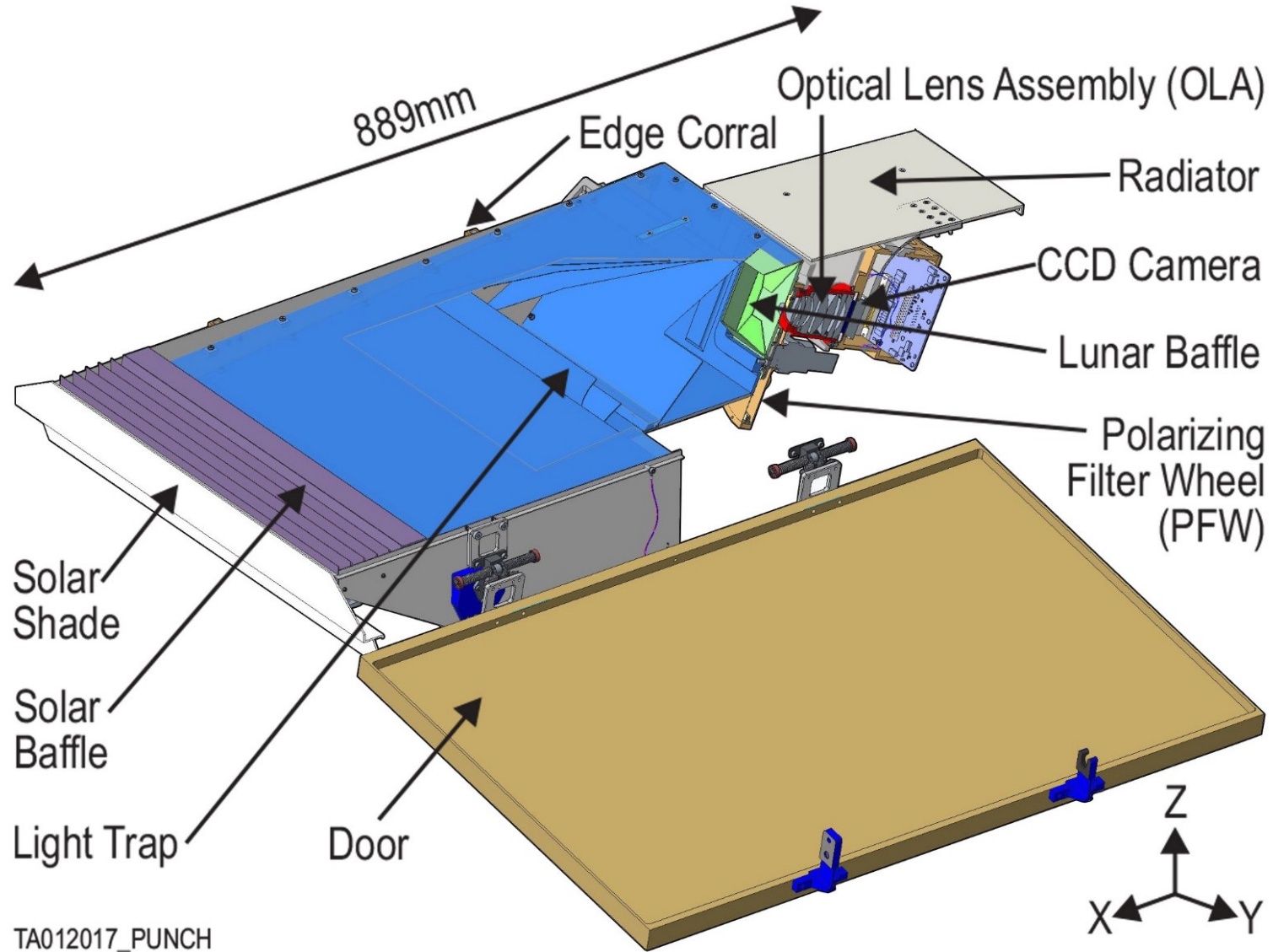


Resource	CBE	Cont.	Total
Mass (kg)	17.05	3.37%	17.63
Power (W)	16.58	9.47%	18.15
Length (mm)	889	-	889
Width (mm)	438	-	438
Height (mm)	149	-	149
Data Rate (GB/day)	1.41	34.20%	

* LV update provides additional margin



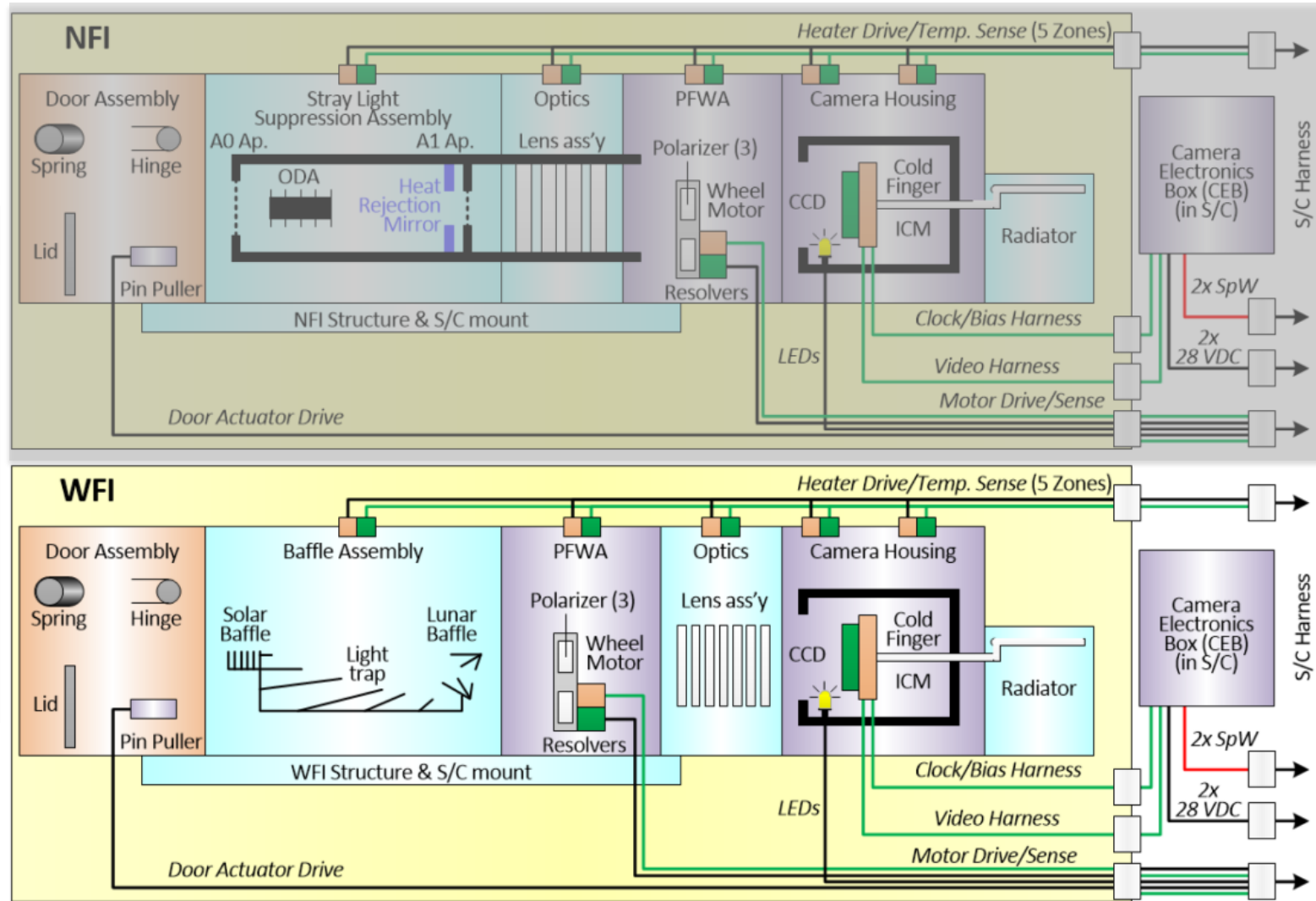
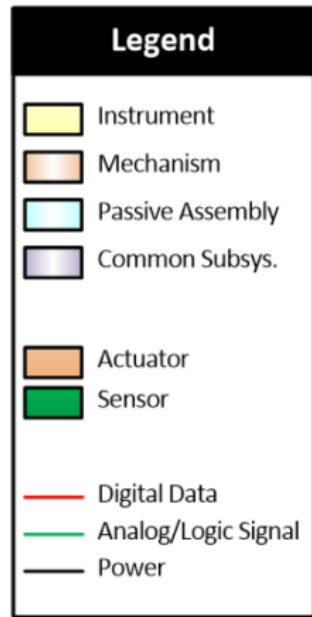
WFI Instrument



TA012017_PUNCH



WFI Block Diagram





WFI Level 2 Driving Requirements

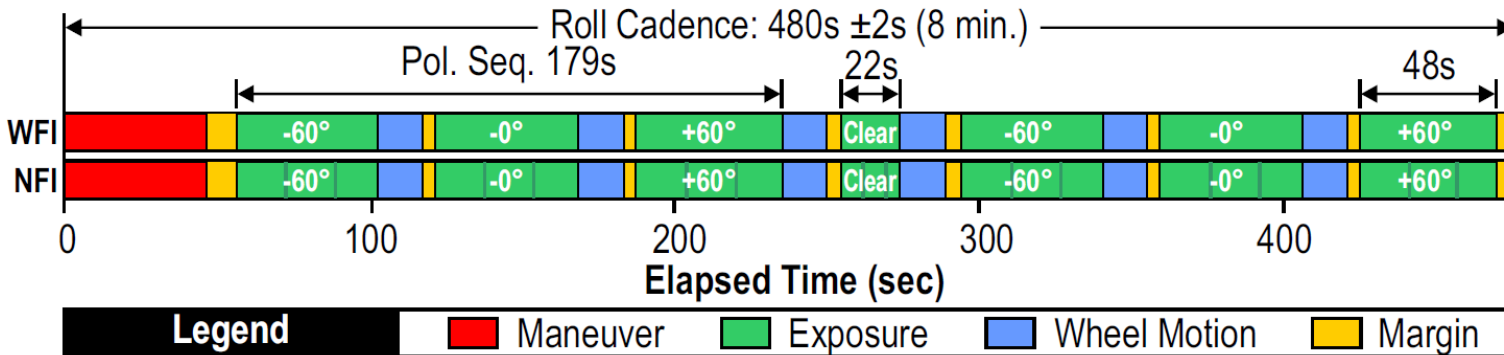
- WFI science requirements are clearly defined and performance shows robust margin.

ID	Requirement	Value	Performance	Margin
1057	Passband	Width: 300+/-100nm Center: 550+/-75nm	450-750nm	Complies
1063	Field of View (FOV)	20 R _☉ – 160 R _☉	17.4 R _☉ – 180R _☉	16%
1064	Instantaneous FOV	40 deg ^o square truncated by 50 deg ^o circle	40.2° FOV Baffle, >50° OLA FOV	Complies
1068	Angular Resolution	4 arcmin	2.4 arcmin	67%
1071	Norm. Sensitivity	7E-17 B _☉	3.7E-17 B _☉	90%
1076	Polarization	3 angles	-60°, 0°, +60°	Complies



WFI Conops

- Conops common to WFI & NFI
- Two sets of polarization sequences per 8 min roll cadence
- 20 seconds PFW rotation time



TA010788-PUNCH

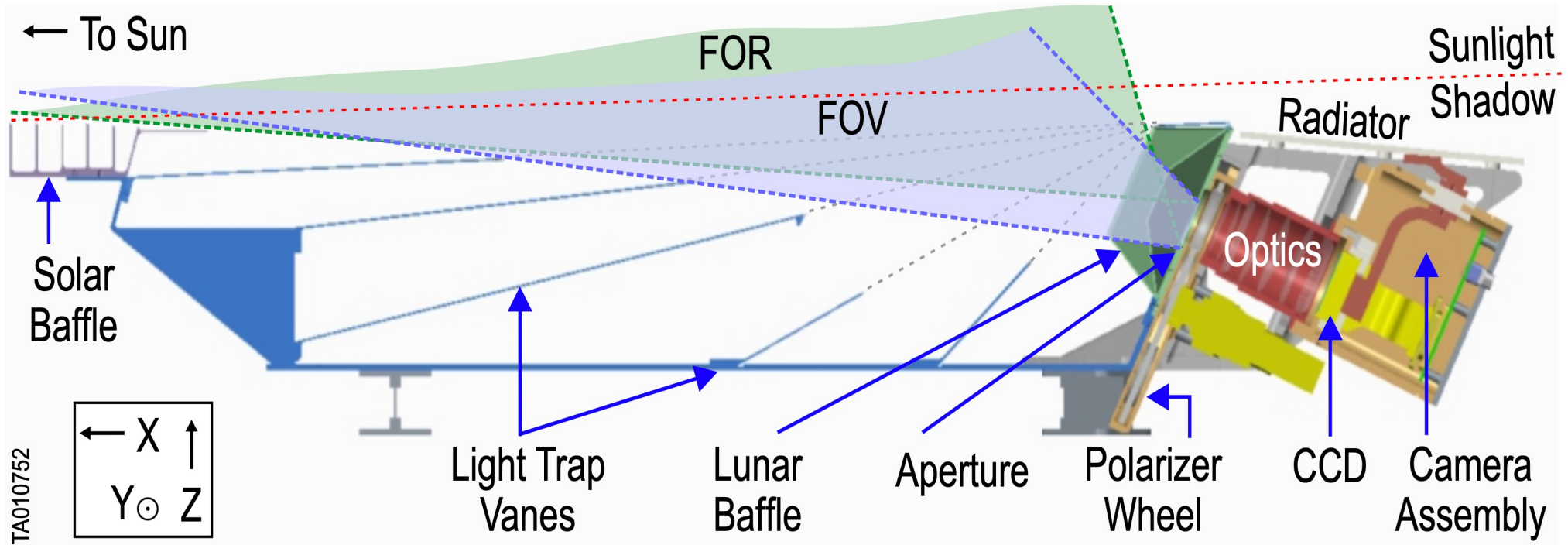
PUNCH Observing Sequence Schedule

Time (s)	Length + margin	NFI Action	WFI Action
0	47+4	Roll & set PFW to -60°	Roll & set PFW to -60°
51	48+1(*)	Expose 3x13s at -60°	Expose 45s at -60°
98	15+5	Set PFW to 0° & settle	Set PFW to 0° & settle
118	48+1(*)	Expose 3x13s at 0°	Expose 45s at 0°
165	15+5	Set PFW to 60° & settle	Set PFW to 60° & settle
185	48+1(*)	Expose 3x13s at 60°	Expose 45s at 60°
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° & settle	Set PFW to -60° & settle
293	48+1(*)	Expose 3x13s at -60°	Expose 45s at -60°
340	15+5	Sep PFW to 0° & settle	Sep PFW to 0° & settle
360	48+1(*)	Expose 3x13s at 0°	Expose 45s at 0°
407	15+5	Set PFW to 60° & settle	Set PFW to 60° & settle
427	48+1(*)	Expose 3x13s at 60°	Expose 45s at 60°
474	1 to 11	Sync for next roll	Sync for next roll

(*) 2-second overlap with following event



WFI Optics Overview



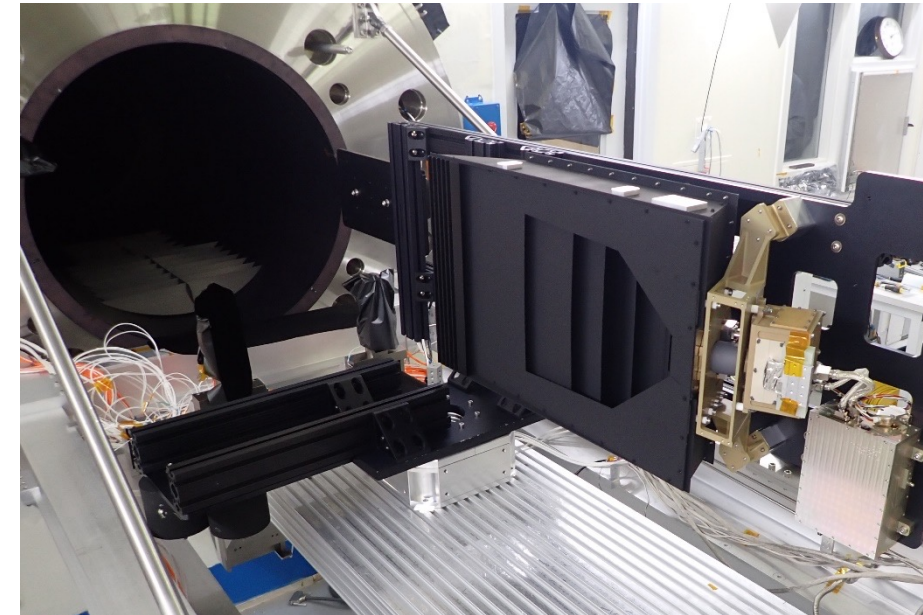
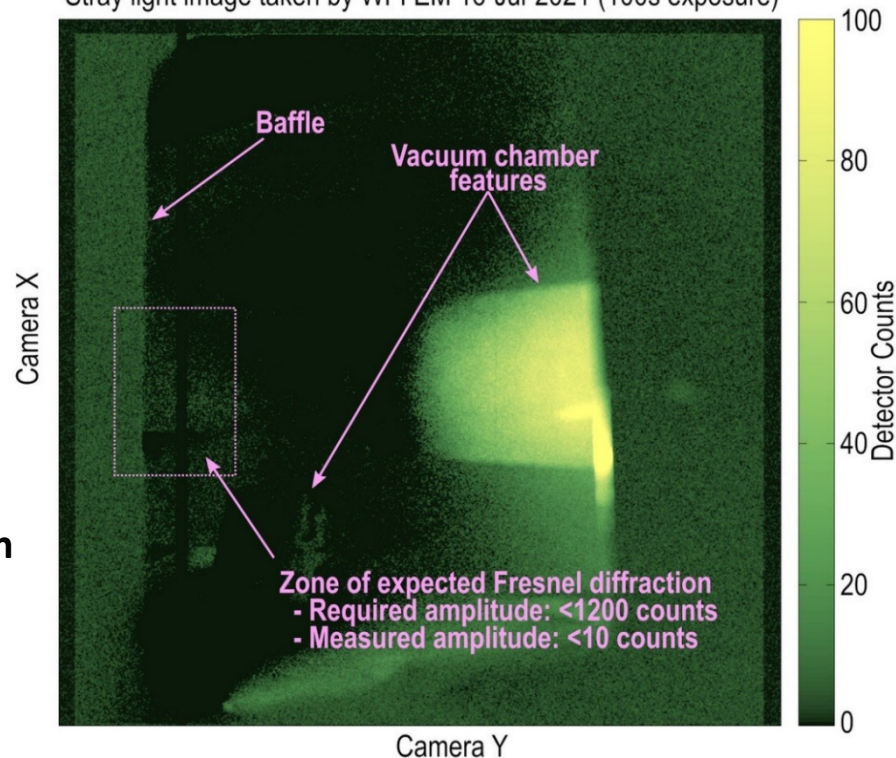


EM WFI – Solar Stray Light Attenuation

Req ID	Req. Title	Requirement / Rationale	Performance	Compliance	Verification
3.1.8	Stray Light Attenuation	The WFI instrument shall have instrumental background below 2E-16 B _⊙ due to stray light from all sources.	2E-18 (SCOTCH)	Compliant	Measure (SCOTCH)

- EM WFI Instrument testing @ SCOTCH
- 100s, 300sec imaging
- Differential signal measures stray light @ Inner FOV
- 2E-16 B_⊙ Stray light requirement → 1200 DN / pixel
- As-Measured Amplitude → 10 DN/pixel
- **Stray Light performance met with 100x Margin**

Stray light image taken by WFI EM 16-Jul-2021 (100s exposure)

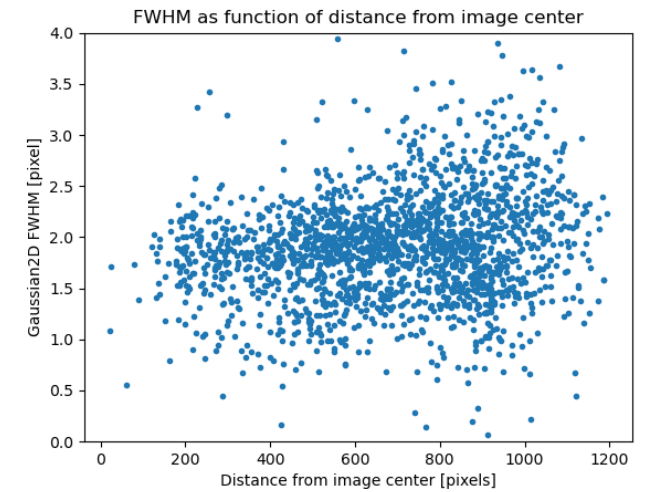
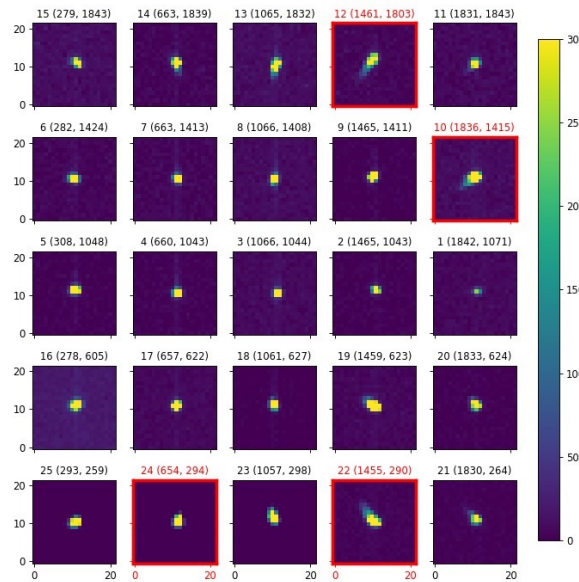
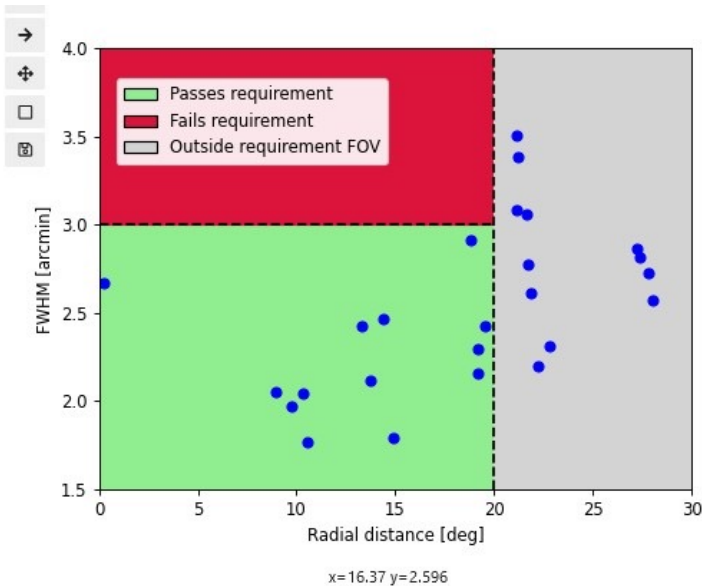
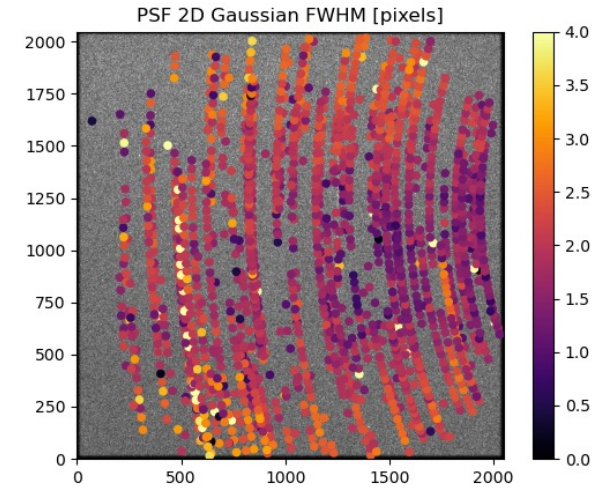




OLA – Optical Lens Assembly

Req ID	Req. Title	Requirement / Rationale	Performance	Compliance	Verification
5.4.6	OLA Resolution	The WFI OLA shall have a maximum FWHM spot size of 3 arcminutes (projected) with a broadband source. (Flowdown from 1009)	1.9 arcmin (Model) 2.4 arcmin (Point Source imaging)	Compliant	Test (Starfield / Point Source)

- FM WFI-1 OLA Point Source testing
- OLA-to-CCD focal distance adjusted with housing shims



- EM WFI Starfield testing

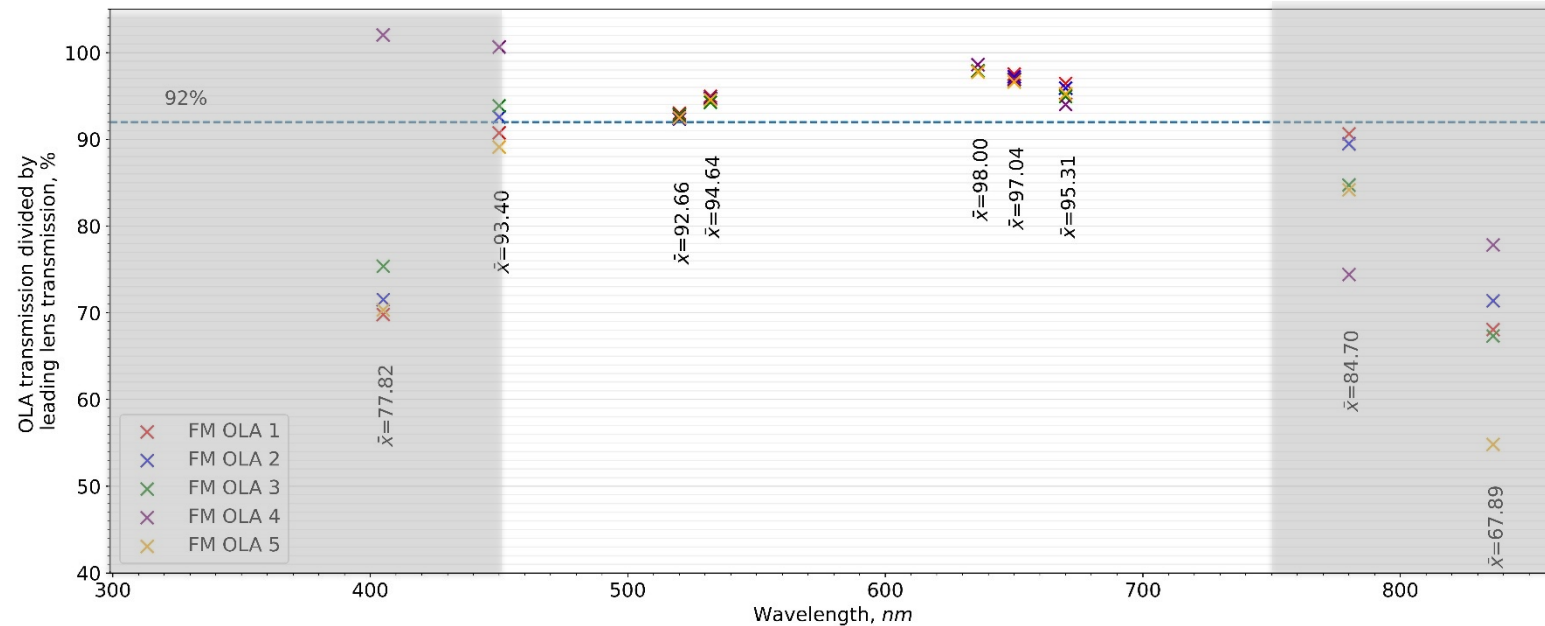
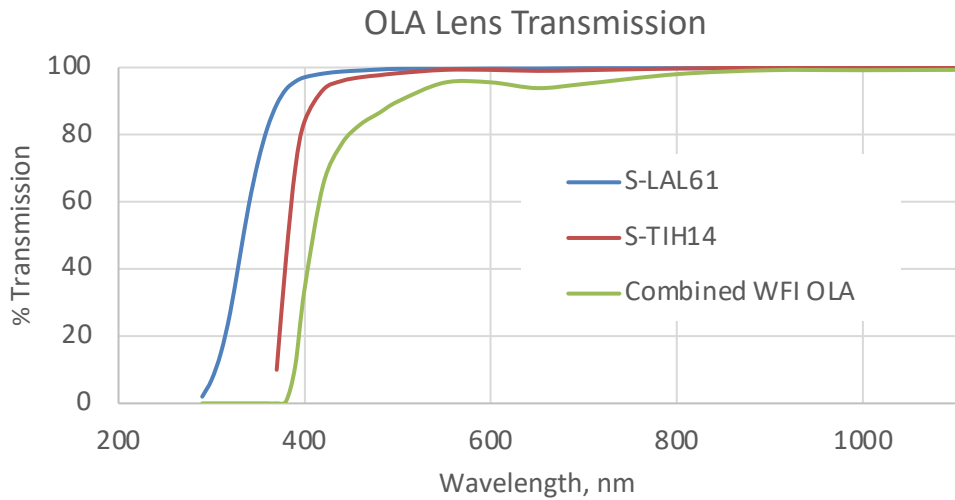


FM OLA – Transmission

Req ID	Req. Title	Requirement / Rationale	Performance	Compliance	Verification
5.4.3	OLA Transmission	The WFI OLA shall have a BOL in-band transmission of >92% averaged over the operational passband. (Flowdown from 1006)	96% (Model) 96% (FM Laser testing)	Compliant	Test (Monochromatic light)

- WFI OLA Model
96% throughput

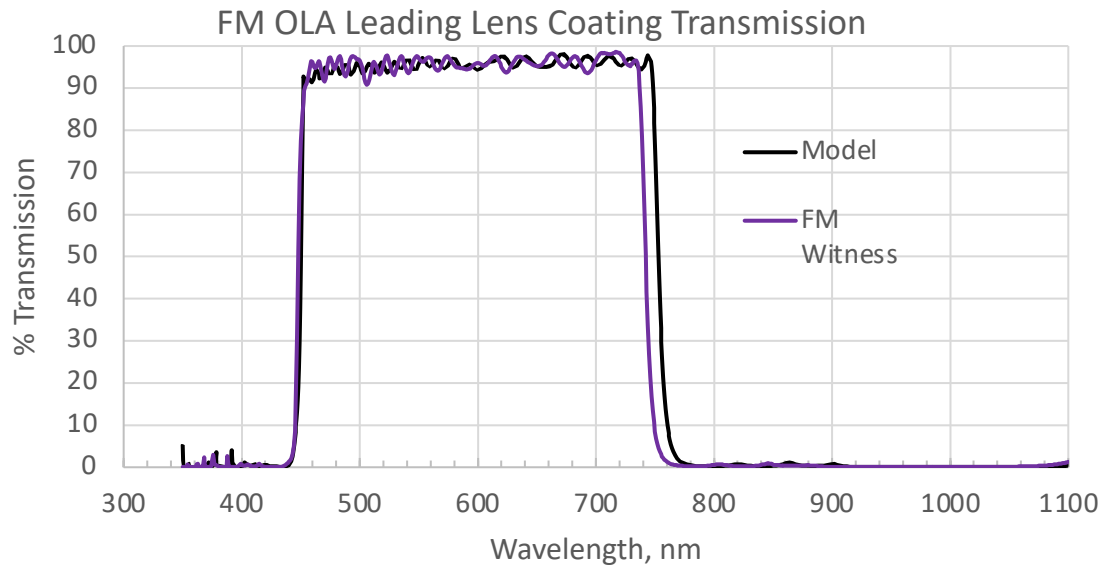
- WFI FM OLA
96% throughput (corrected for passband coating transmission)



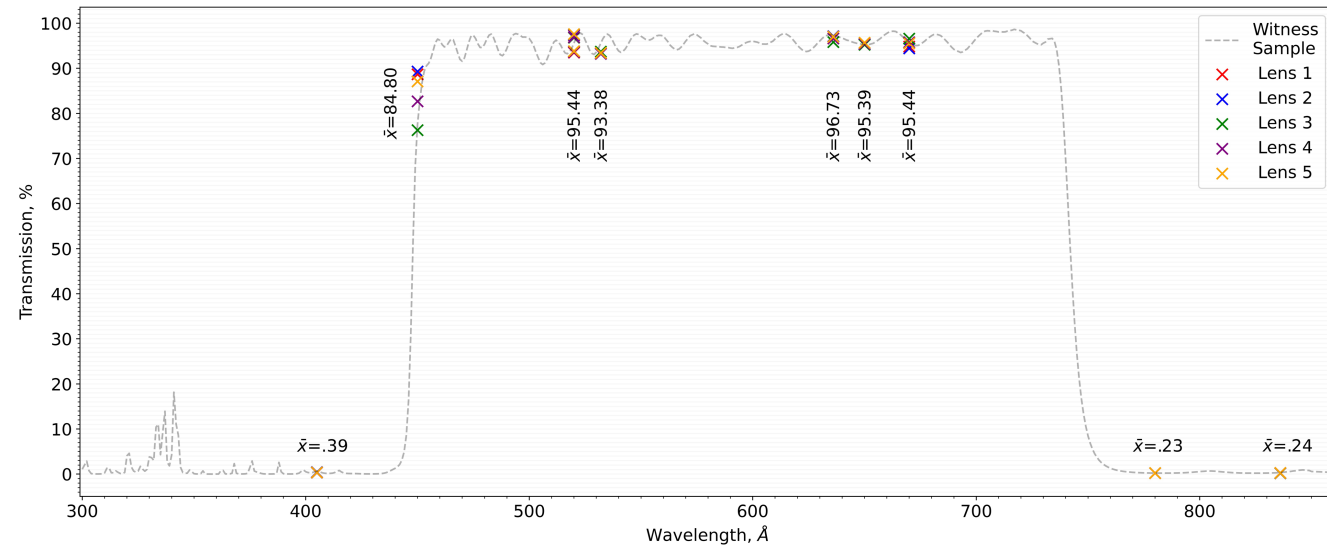


FM OLA – Out-of-Band Rejection

Req ID	Req. Title	Requirement / Rationale	Performance	Compliance	Verification
5.4.12	OLA Out-of-Band Rejection	<p>The WFI OLA leading lens shall have an out-of-band rejection coefficient ($1/T_{\text{outofband}}$) of 100 or greater, averaged from 350nm to 1100nm excluding the instrument passband. (Flowdown from 1040)</p> <p>Precludes out of band light from either scattering within the instrument or decreasing the resolution.</p>	<p>227 (EM Testing)</p> <p>359 (FM Testing)</p>	Compliant	<p>Test (Monochrometer) (Laser)</p>



- All FM OLAs yield > 300 OOB rejection

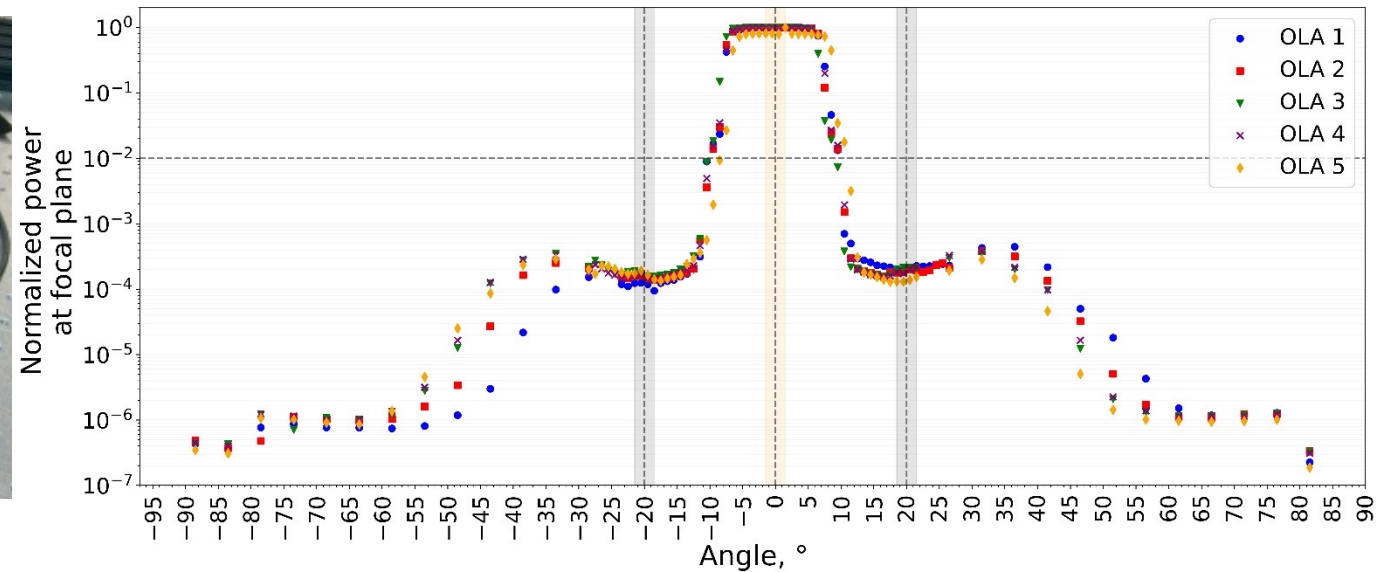
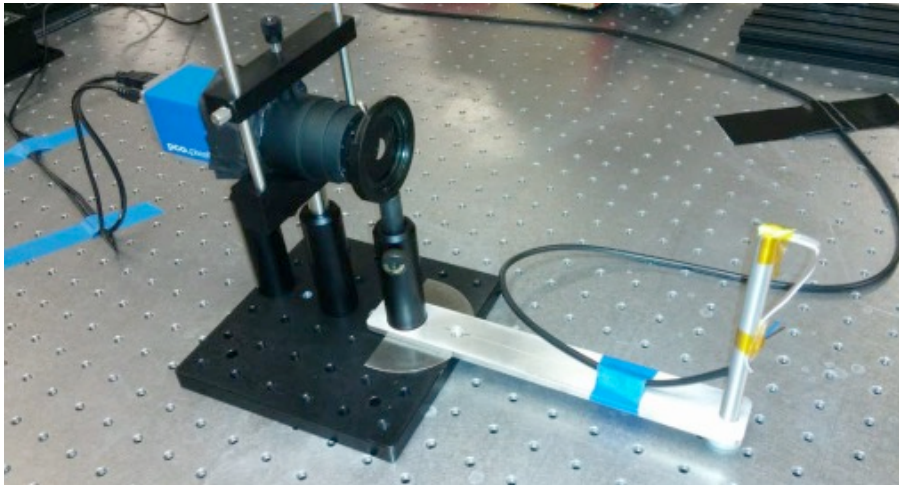




FM OLA – Off-Axis Scatter

Req ID	Req. Title	Requirement / Rationale	Performance	Compliance	Verification
5.4.12	WFI OLA Off-Axis Scatter	<p>The WFI OLA shall have an off-axis stray light rejection ≥ 100 at 20 degrees.</p> <p>(Flowdown from 1011)</p> <p>Provides additional stray light rejection off-axis.</p>	>2000 (EM, FM OLA testing)	Compliant	<p>Test</p> <p>(LED Swingarm Test)</p>

- All FM OLAs yield $> 10^3$ rejection

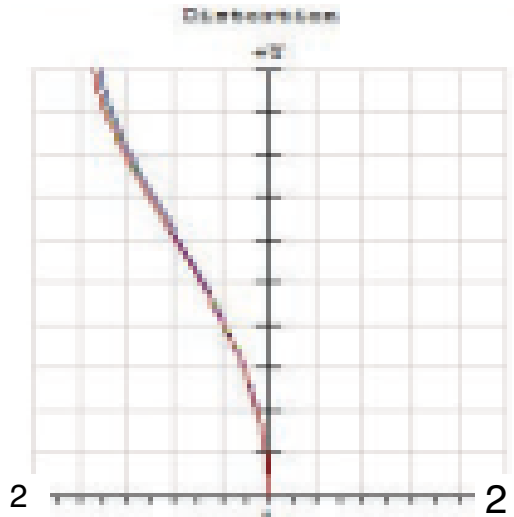




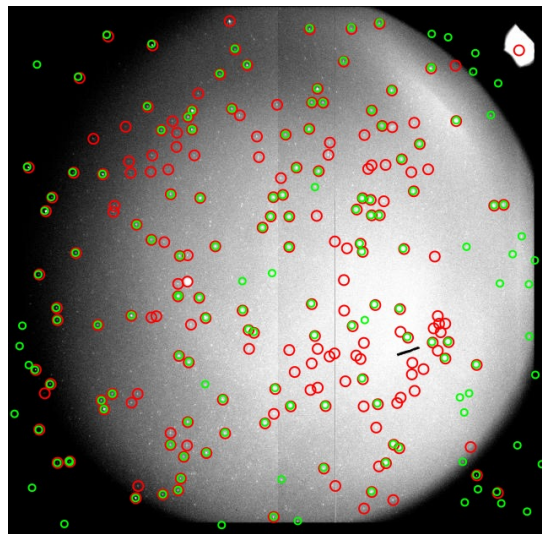
OLA – Distortion

Req ID	Req. Title	Requirement / Rationale	Performance	Compliance	Verification
5.4.11	WFI OLA Distortion	<p>The optical system shall have less than 10% (F-tan theta) distortion over the 40 x 40 degree field of view.</p> <p>(Flowdown from 1011)</p> <p>Simplifies image combination by minimizing amount of differences between edges for combining into mosaics.</p>	<p><1% (Model)</p> <p>0.6% (EM Starfield Imaging)</p>	Compliant	<p>Test</p> <p>(Imaging)</p>

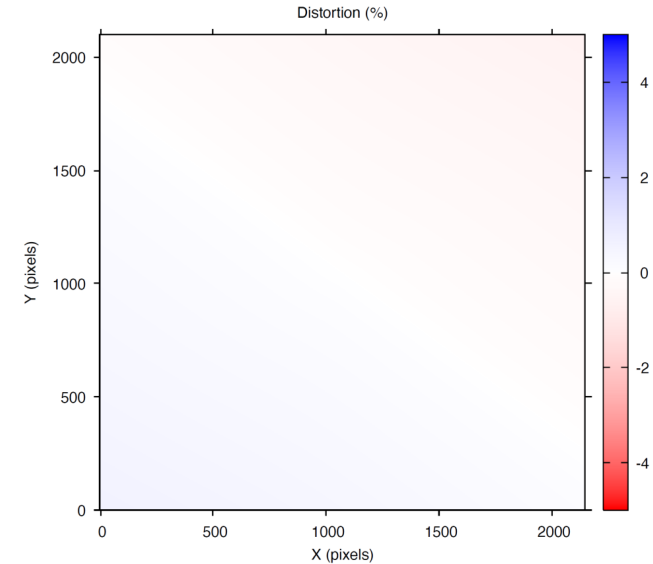
- ZEMAX Simulation yields <1% distortion over FOV.



- EM starfield measurements yield distortion < 0.6% across FOV in all clear/polarized filters.



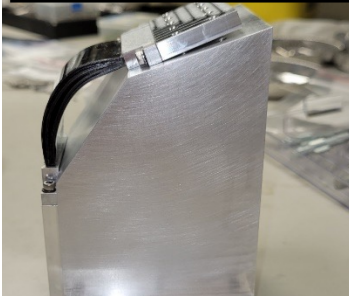
- Pipeline team refining distortion fits to minimize residual non-radial components.



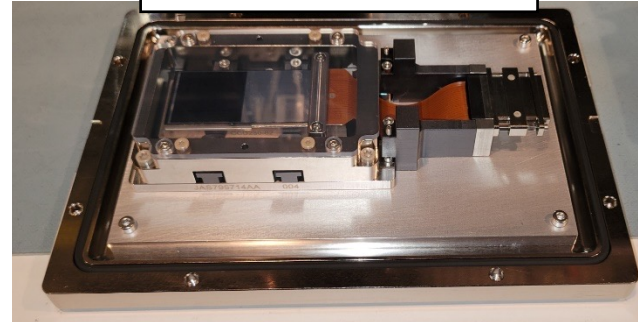


WFI Camera

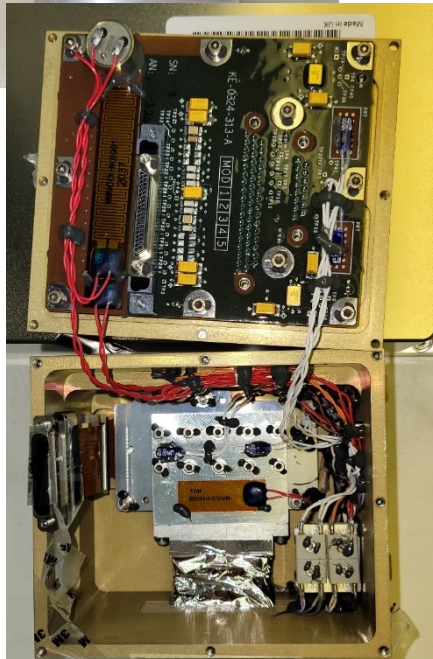
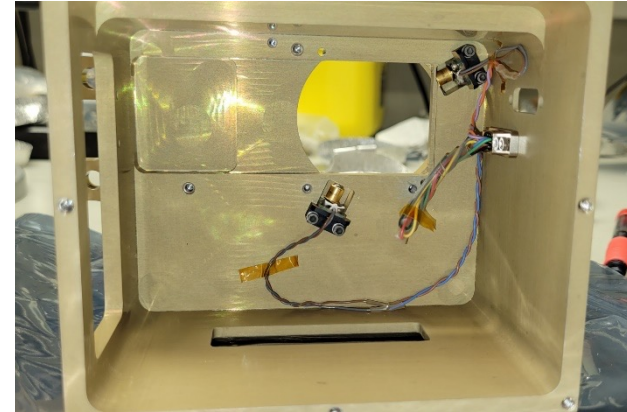
Thermal Strap Vib



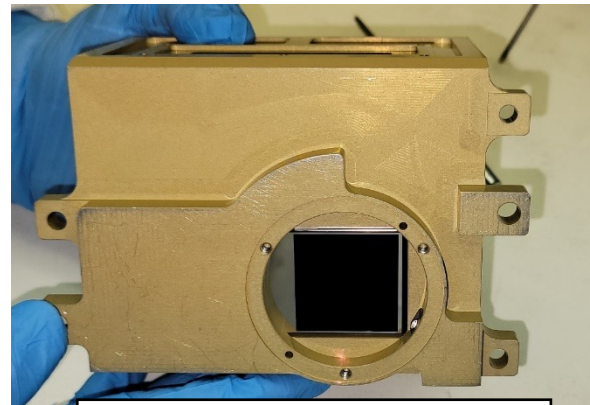
CCD Assembly



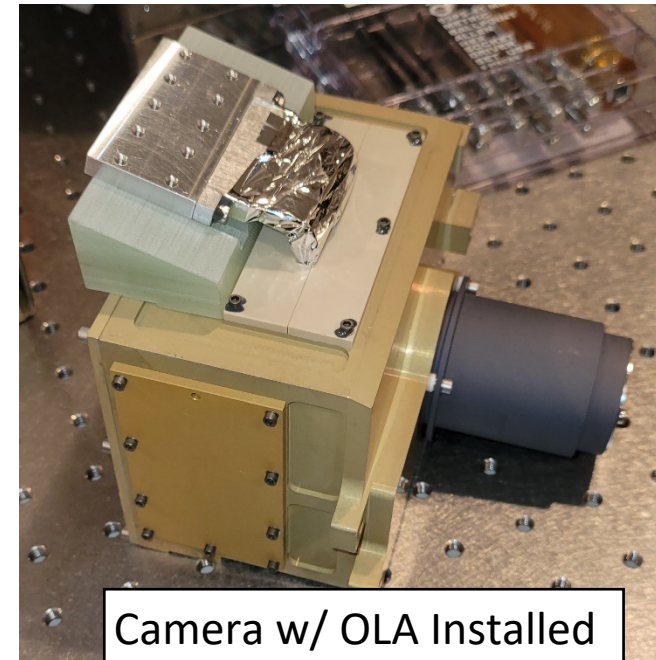
LED Installation



Camera Pre Close Out



Camera Final Assembly

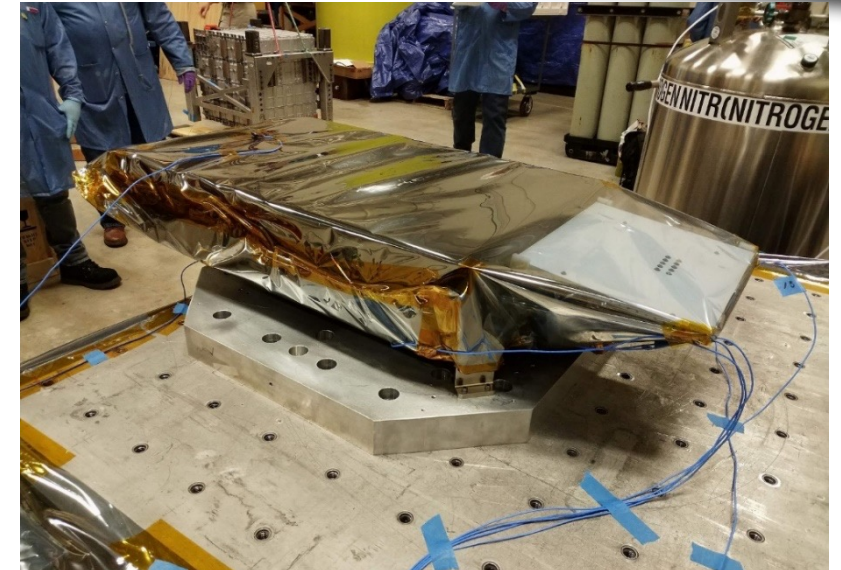


Camera w/ OLA Installed

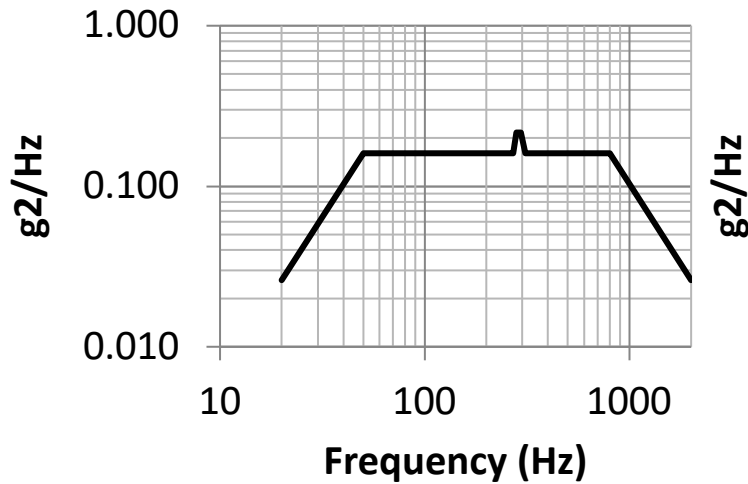


WFI Vibration Testing

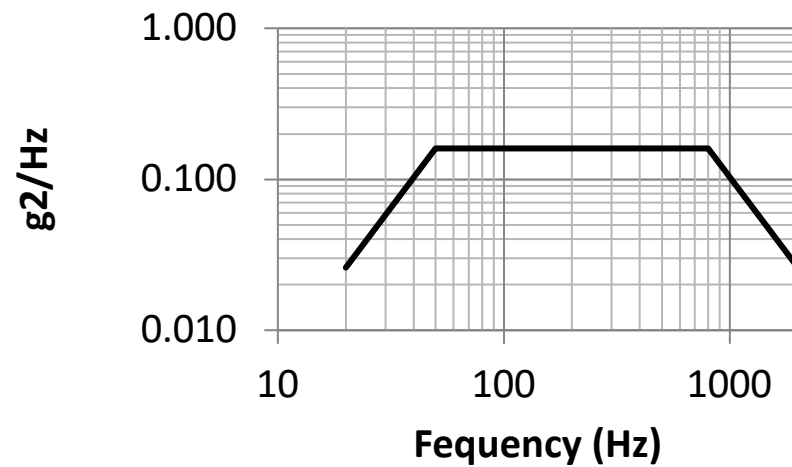
- FM Random vibration loads derived from updated observatory model with launch vehicle inputs
- 3/23 Test failure identified two design deficiencies



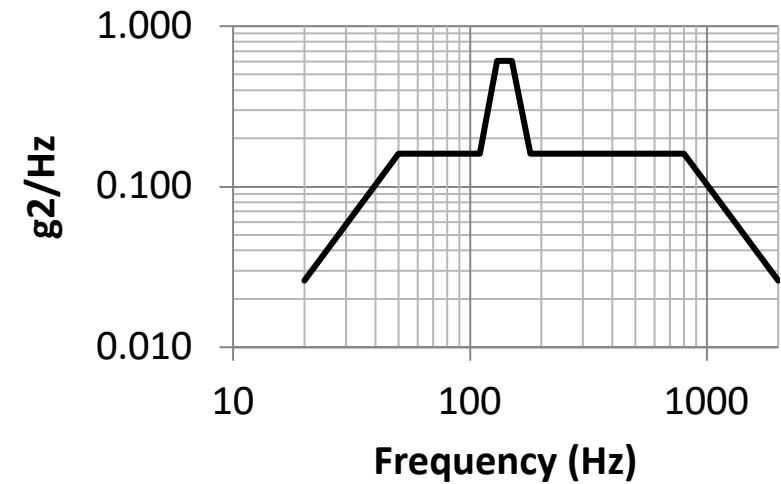
WFI FM Protflight X-Axis



WFI FM Protflight Y-Axis (GEVS)



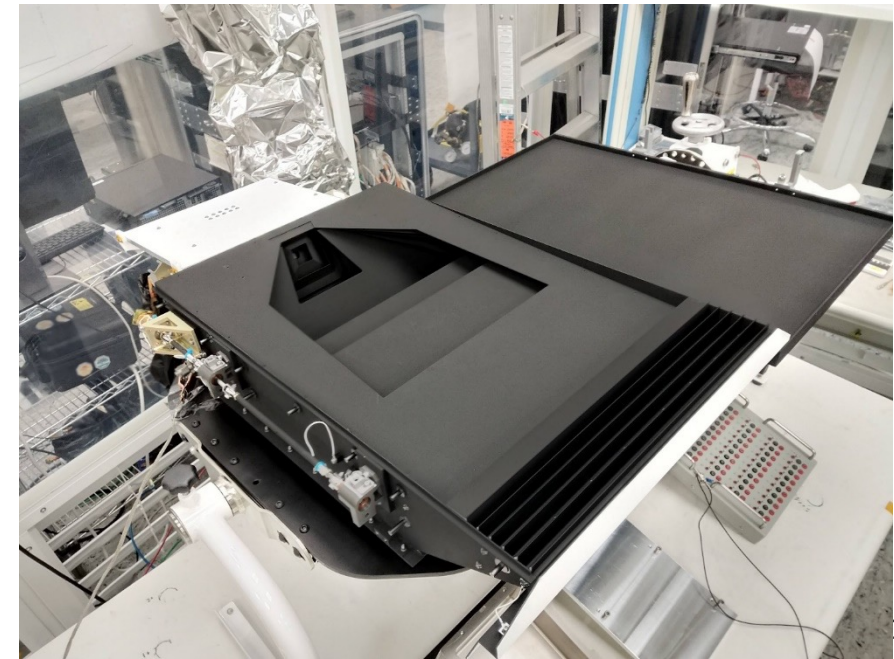
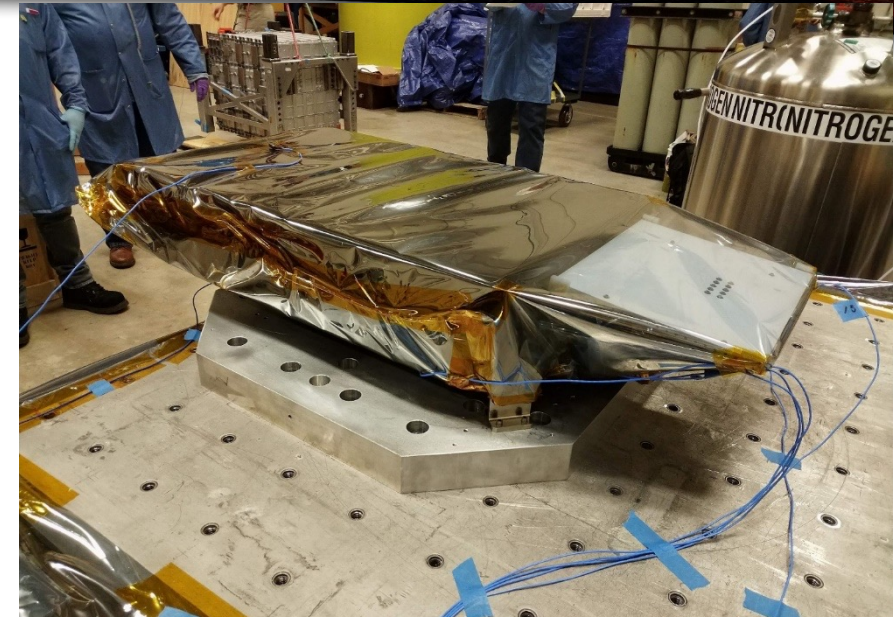
WFI FM Protflight Z-Axis





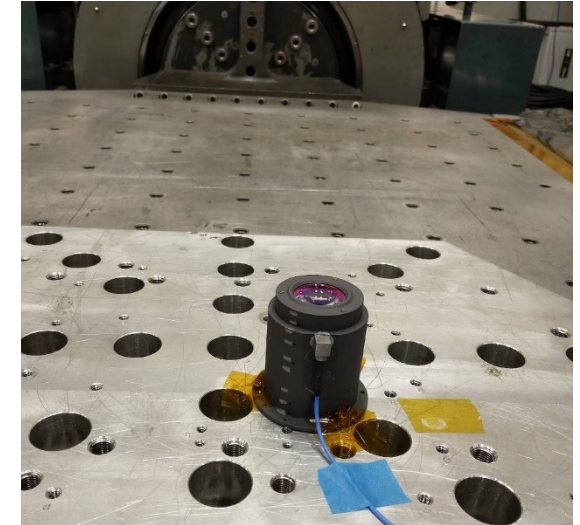
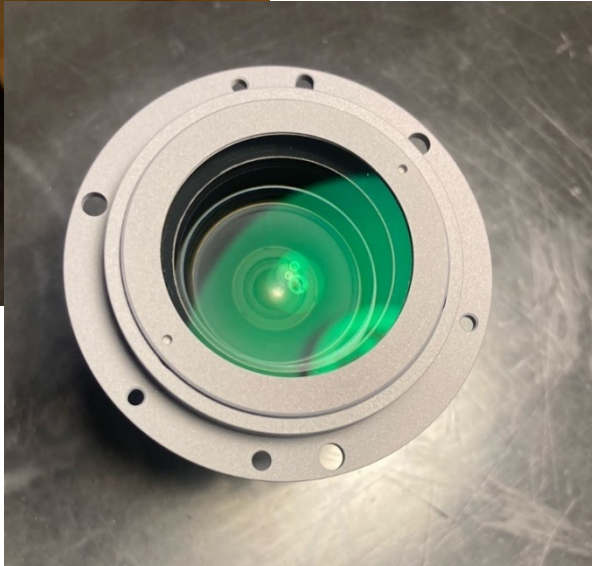
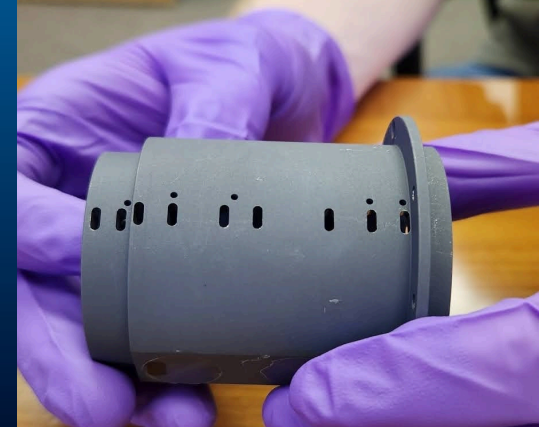
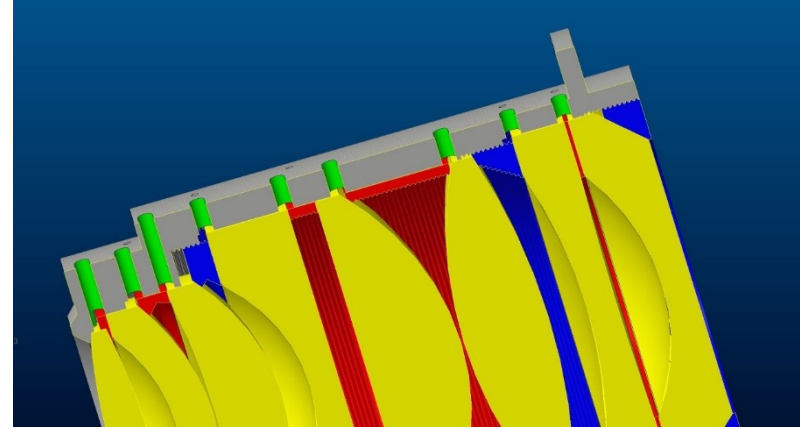
FM WFI Design Updates

- WFI-1 Vibration Test Failure -- Lessons Learned
- WFI OLA Contamination
 - Traced to loss of preload @ Lens 3
 - OLA Housing modification staking of lenses via radial holes
 - Successful Vibration/Thermal Cycling on OLA Flight Spare
 - WFI-1 Modifications complete
- WFI Door Latch
 - Cup/Cone interface causing “stickage” post-vibe
 - Addition of kickoff spring, Modified Ball/Cup design
 - Successful Vibration Testing on EM Door
 - WFI-1 Modifications complete





FM WFI OLAs



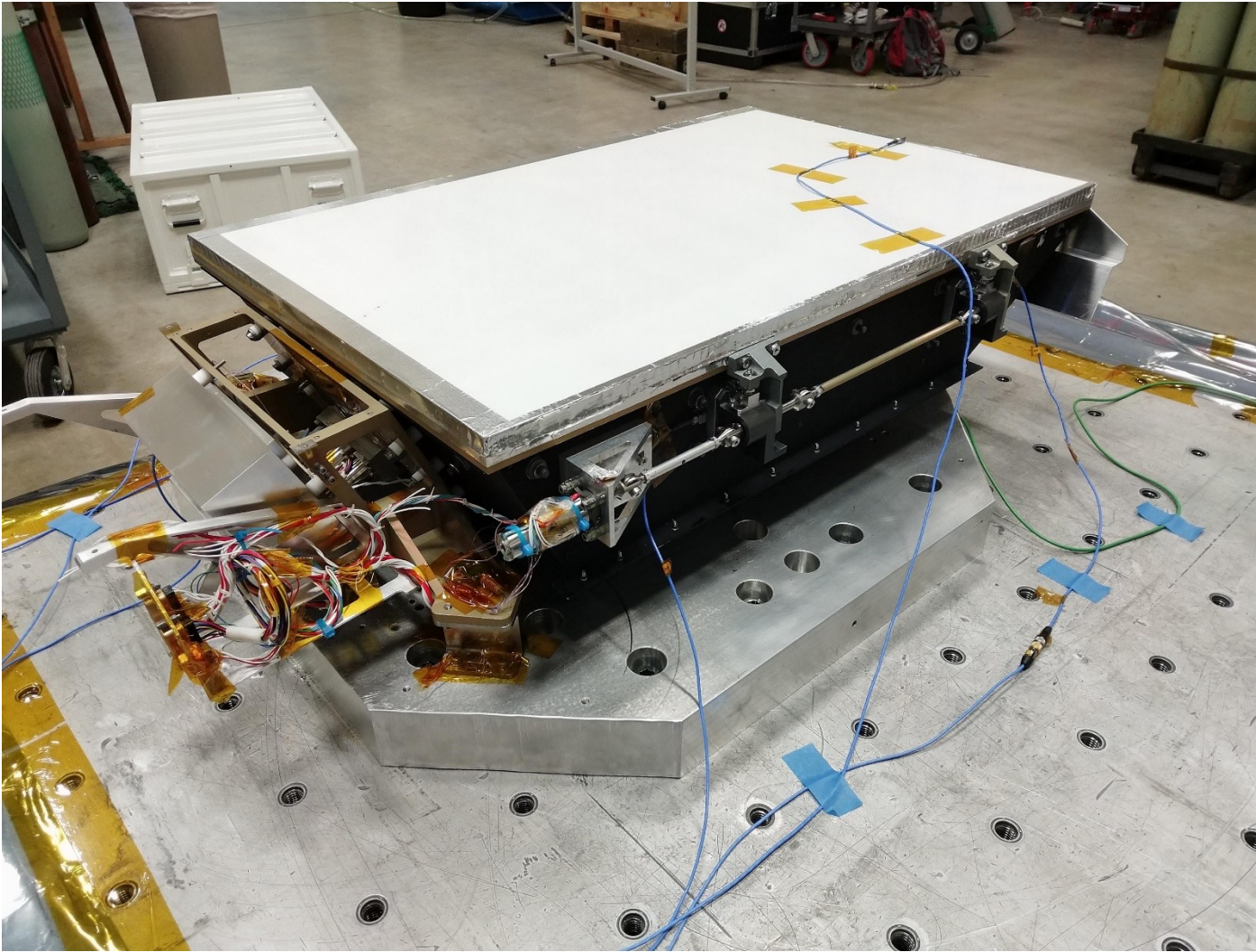
FM WFI OLA pre-assembly QA inspection / fit check

FM WFI OLA Delivery (2 Flight Spares)

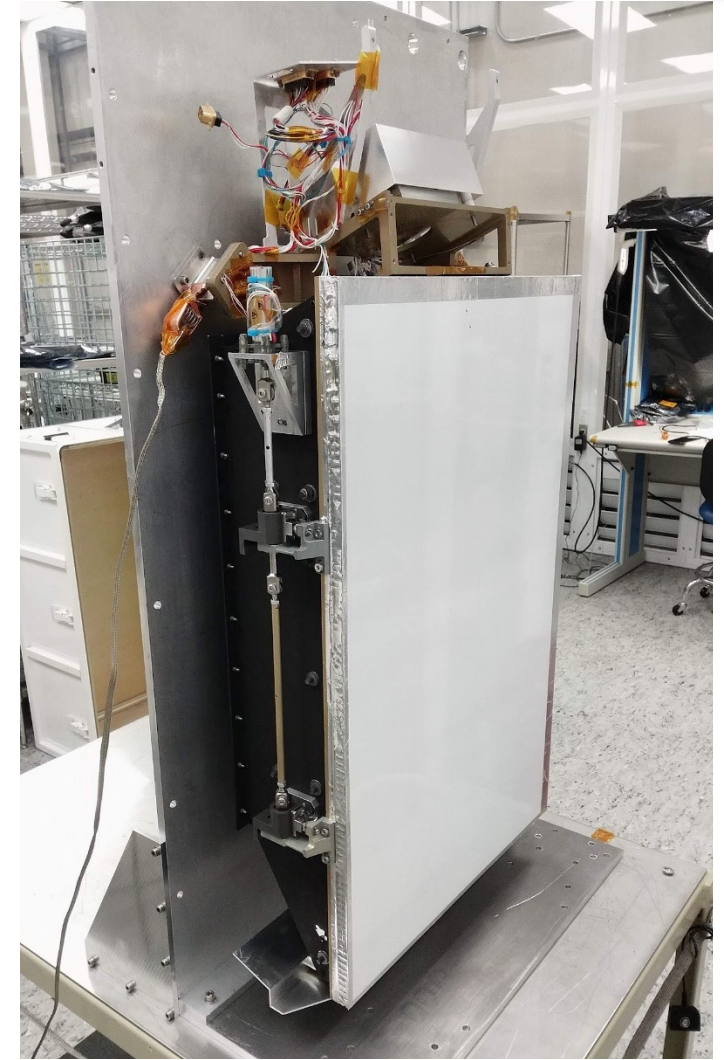
FM WFI OLA Housing Modified



Door Latch Testing



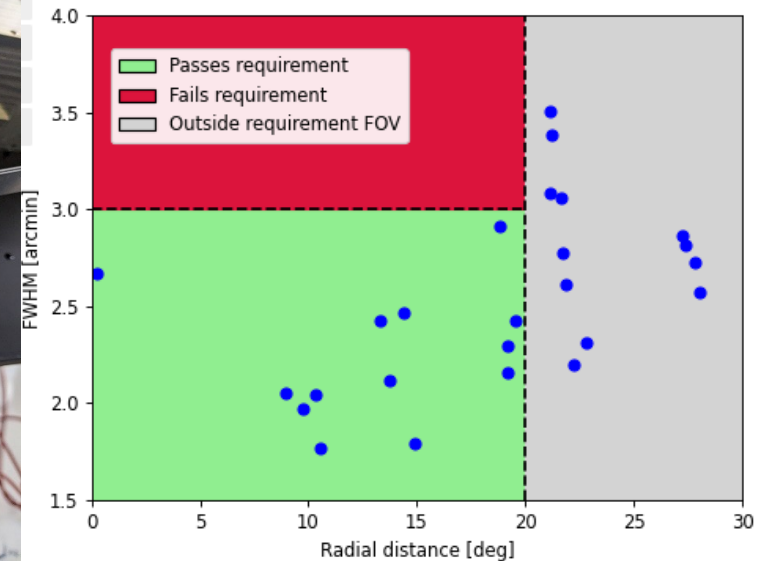
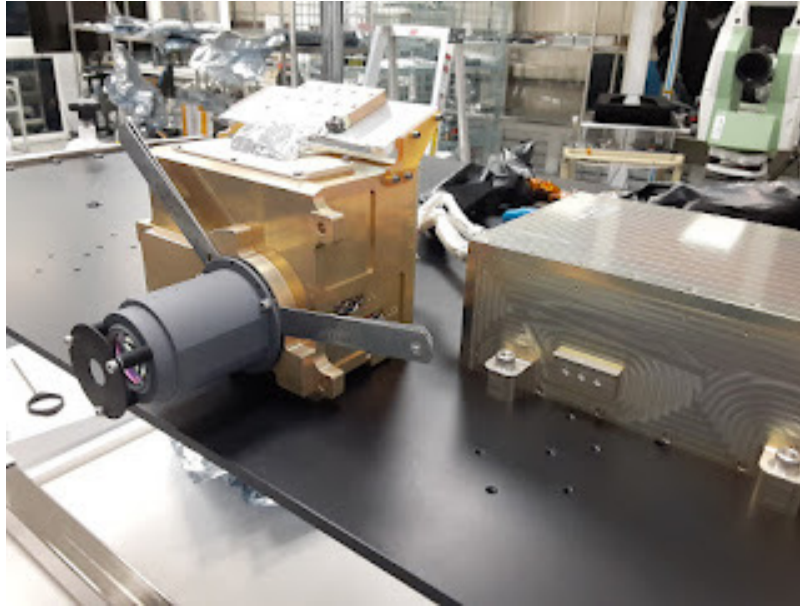
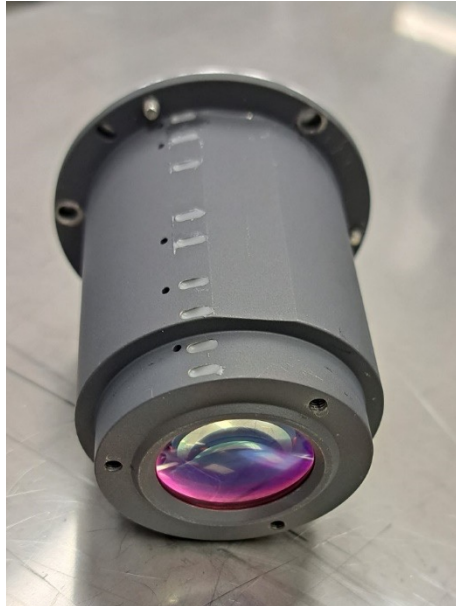
WFI Door Vibration Testing



WFI Door Latch Functional Testing
(post-vibe)



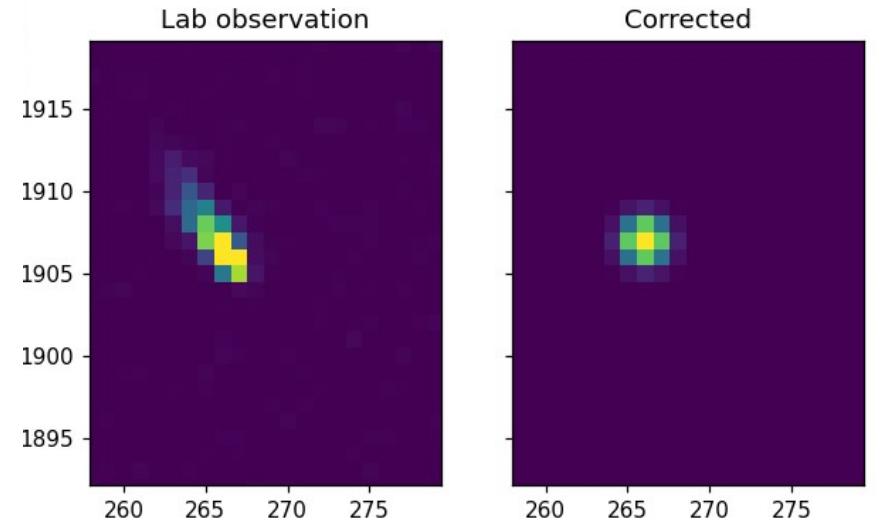
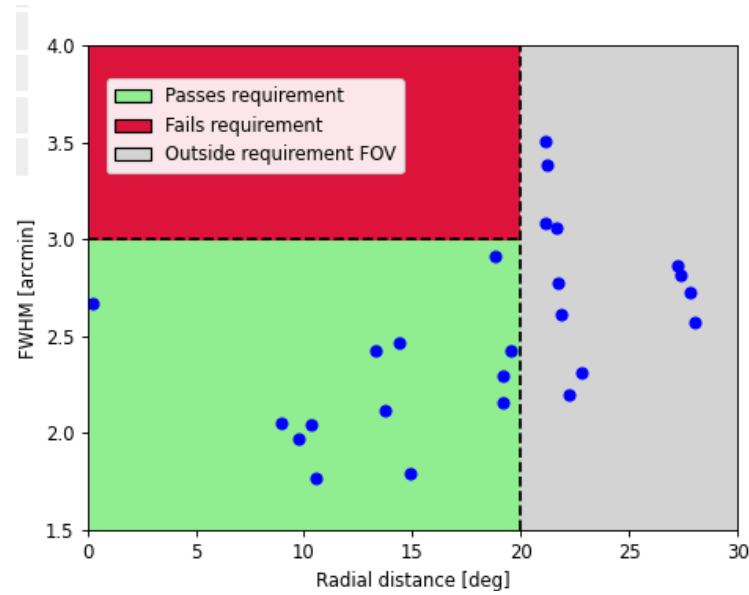
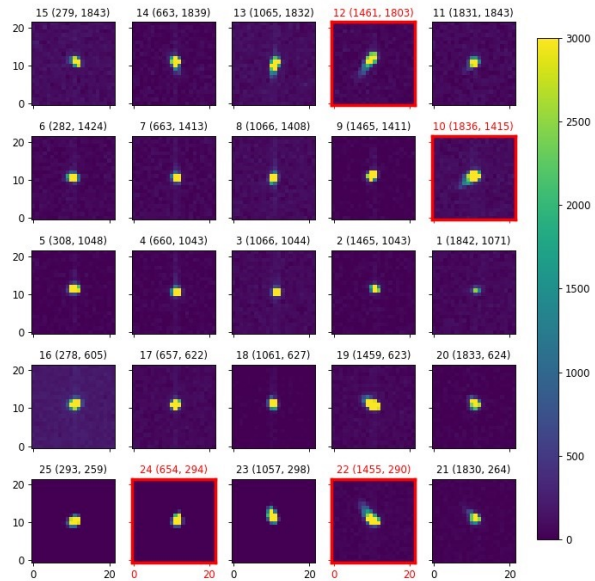
WFI-1 Progress



WFI-1 OLA Modifications & Focus Testing Completed



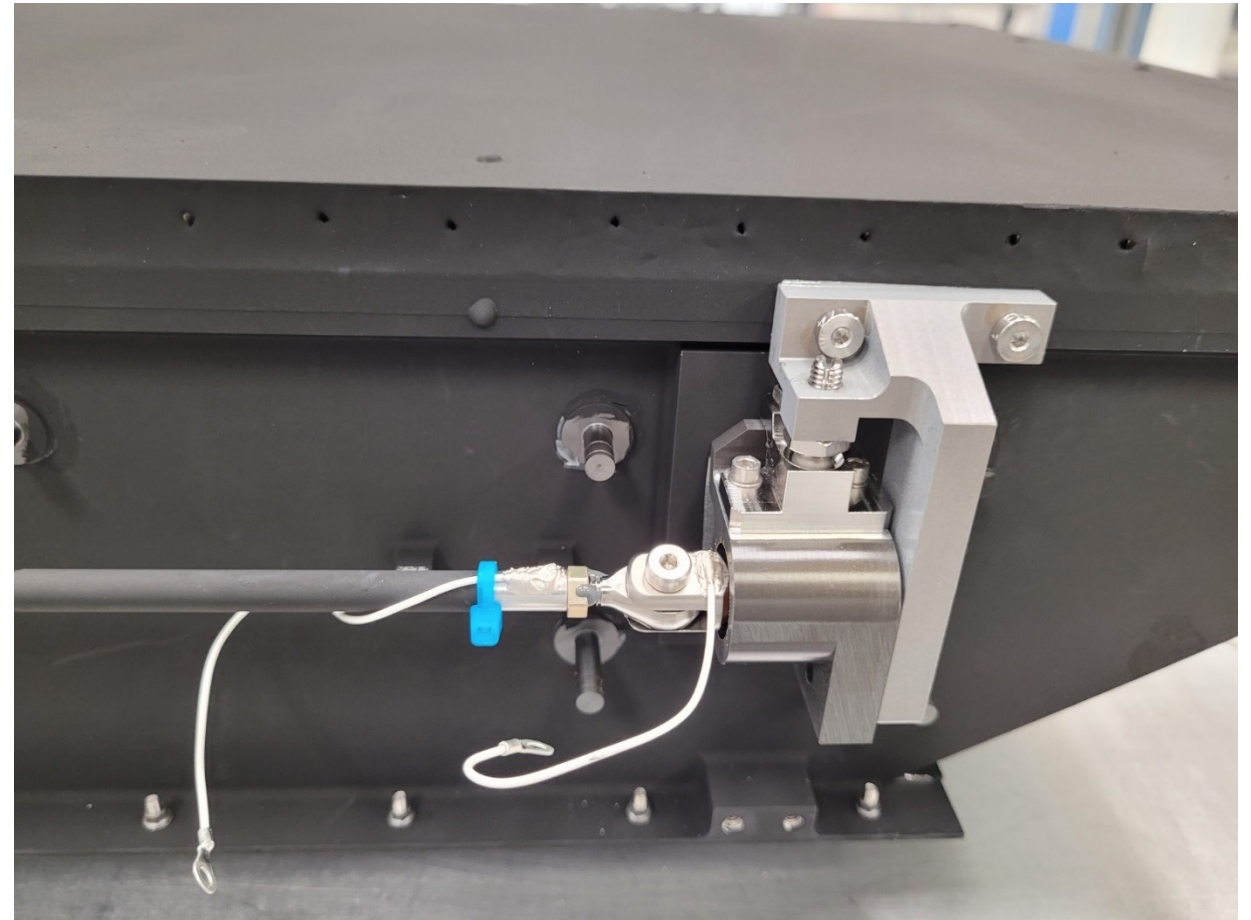
WFI-1 Progress



WFI-1 PSF Regularization



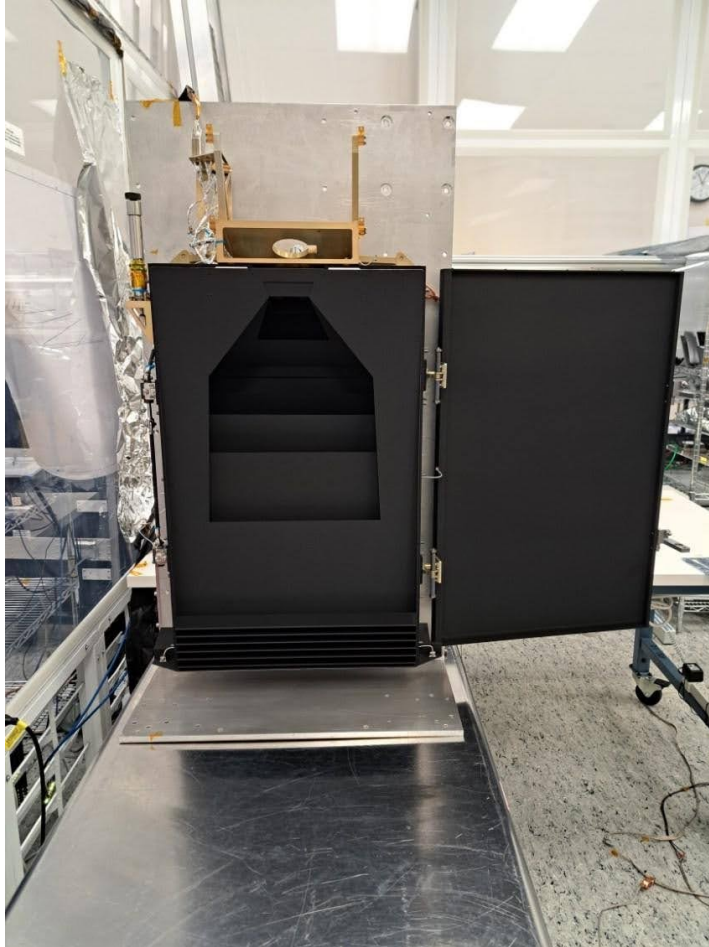
WFI-1 Progress



WFI-1 Door Latch Modifications & Alignment Complete



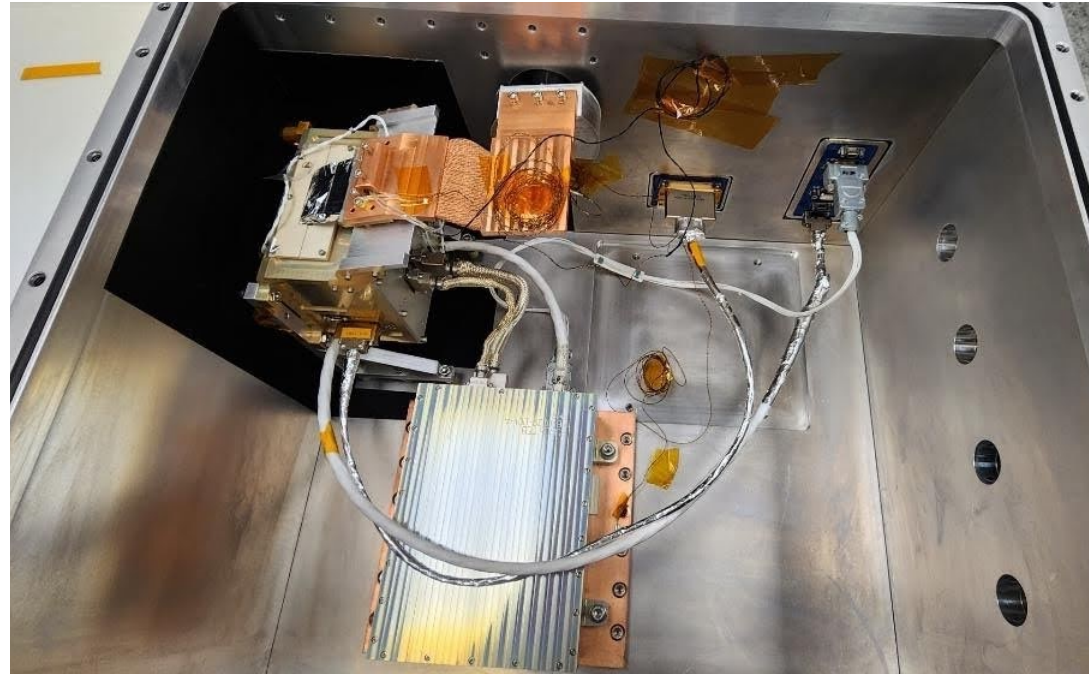
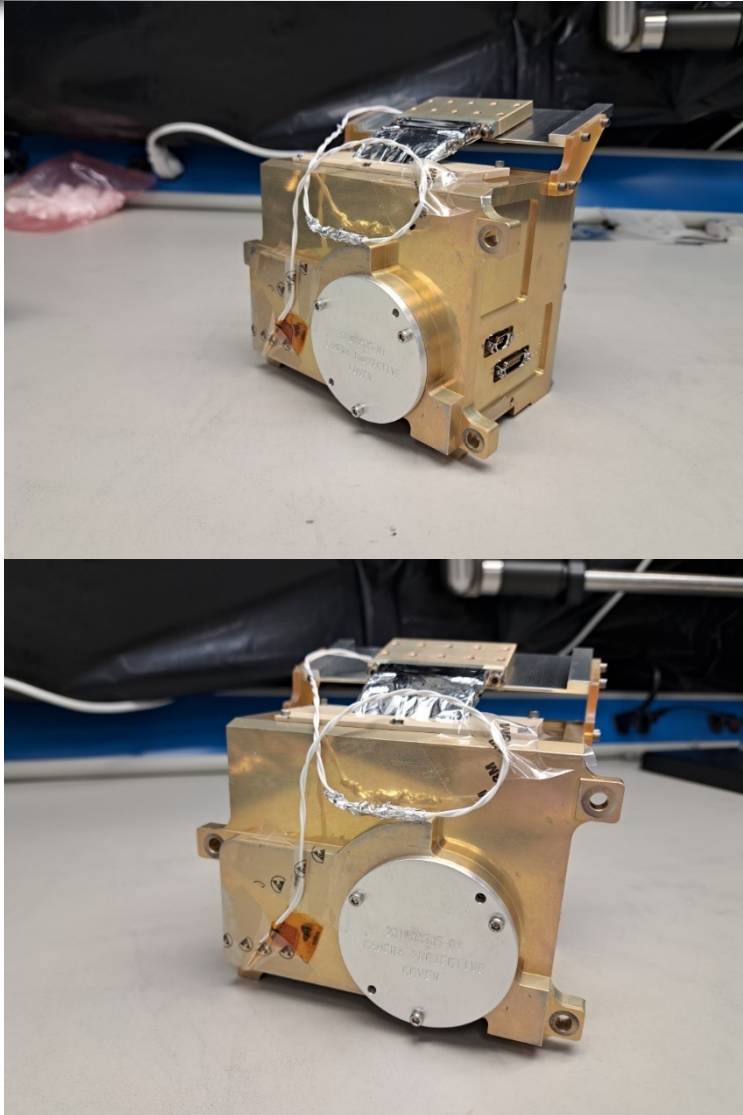
WFI-1 Progress



WFI-1 Door Functional Testing Complete



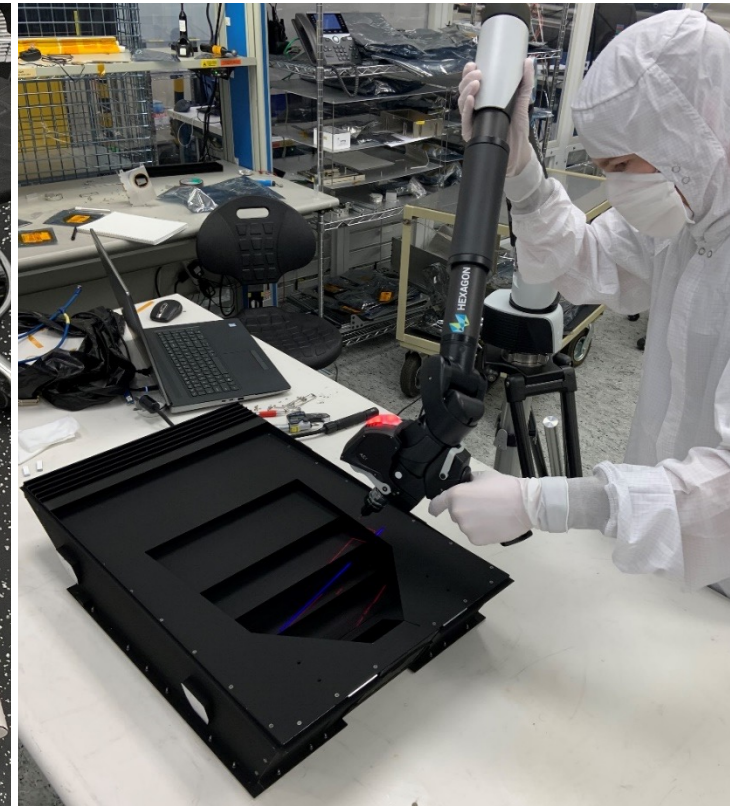
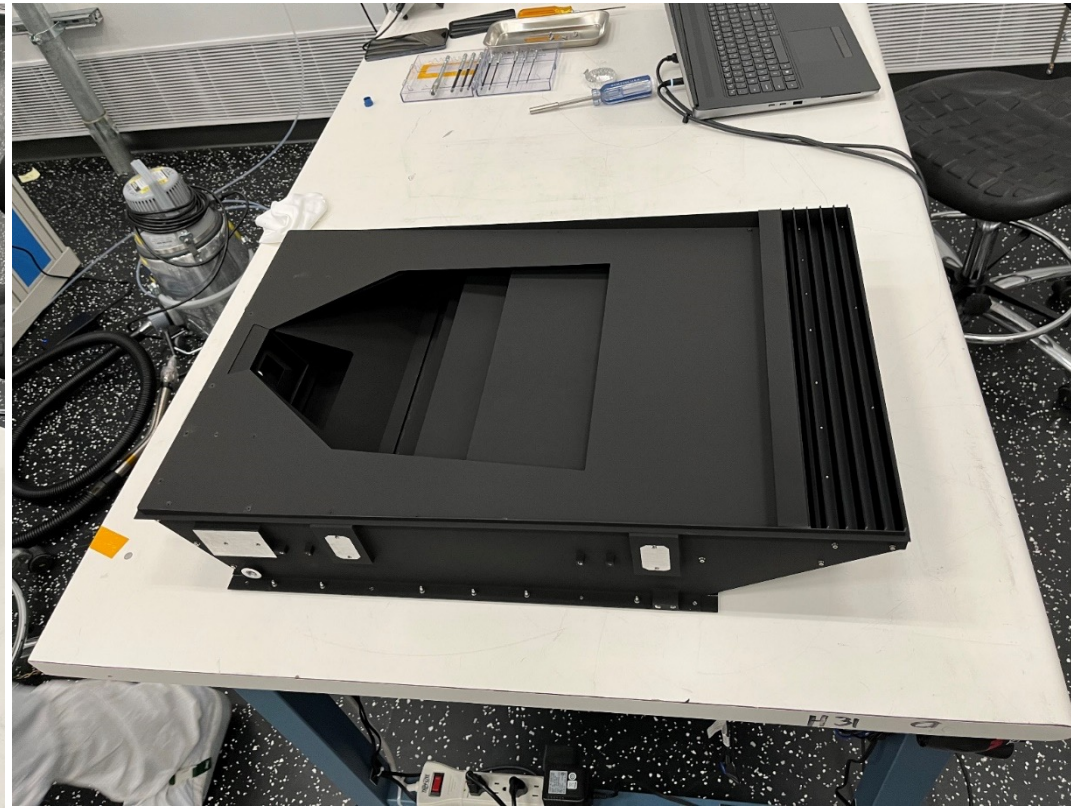
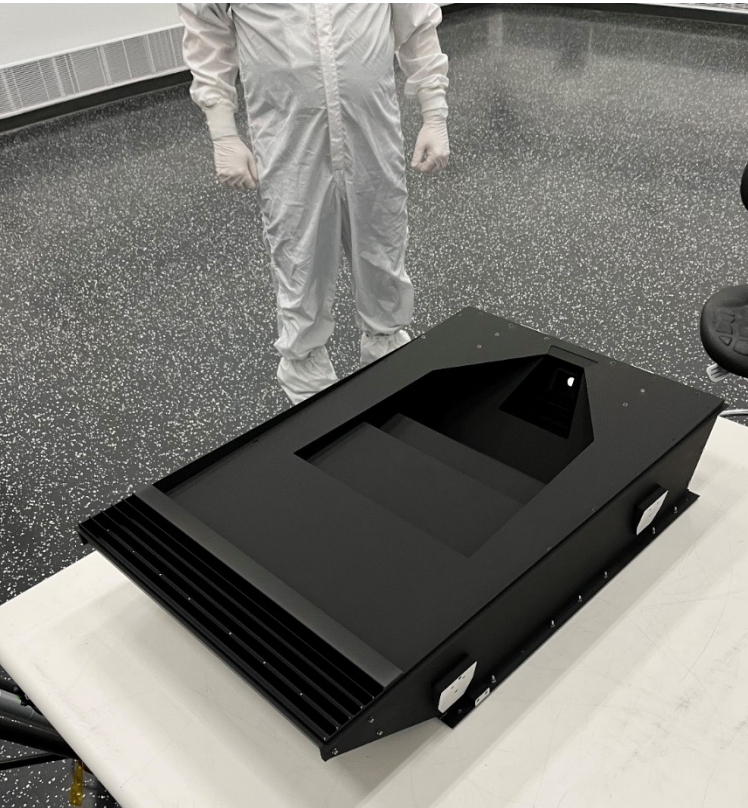
WFI-2 Progress



WFI-2 Camera (FM002) Assembly Completed;
Characterization Testing Underway



WFI-3 Progress

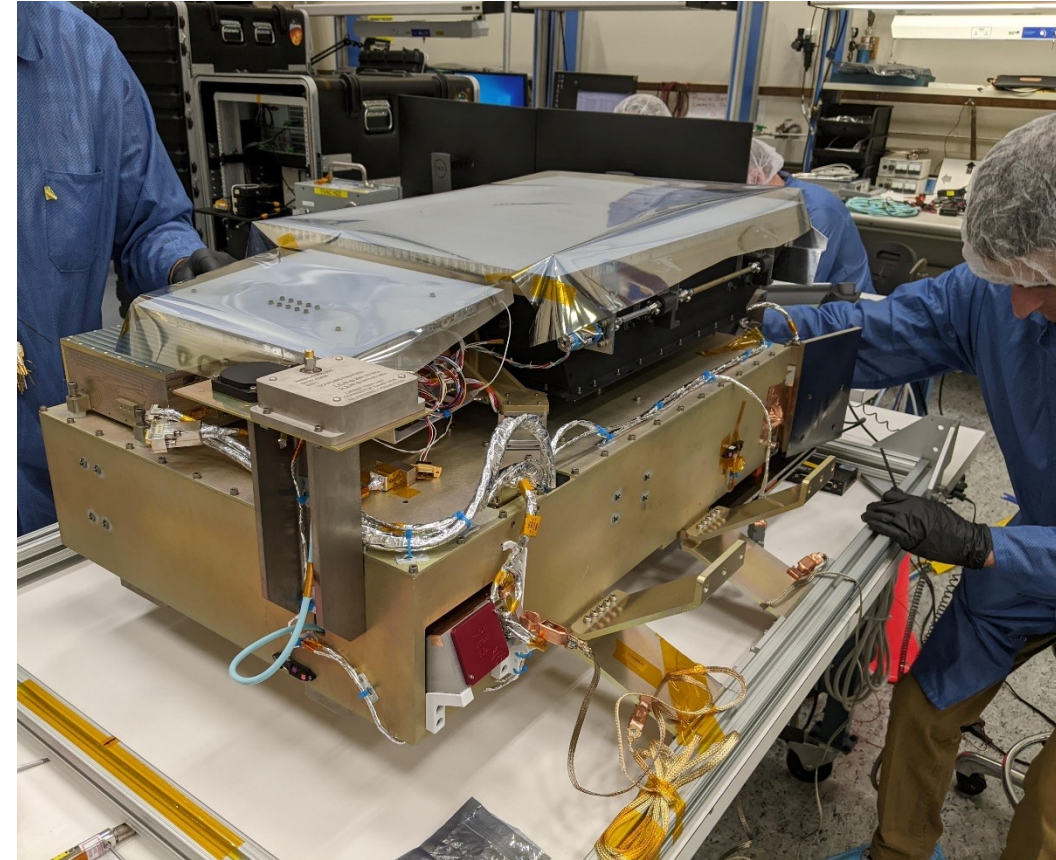


WFI-3 Baffle Completed



WFI Status Summary

- EM WFI Test Campaign Completed
 - EM WFI Delivered to Observatory for EM test campaign
- WFI-1 Integration nearing completion
 - Instrument-Level Performance Checkout 7/10
 - Vibration re-test 7/17
 - TVAC 7/20
 - SCOTCH testing September 2023
- WFI-2 Integration underway
 - FM2 Camera characterization nearing completion
 - FM2 Baffle assembly & testing complete
 - FM2 PFW characterization testing complete
 - Door integration underway
 - OLA integration underway
- WFI-3 Assembly underway
 - FM3 Camera assembly underway
 - FM3 Baffle assembly & testing complete
 - FM3 PFW characterization testing complete
 - OLA housing modifications underway



Polarimeter to Unify the Corona and Heliosphere

Backup Slides



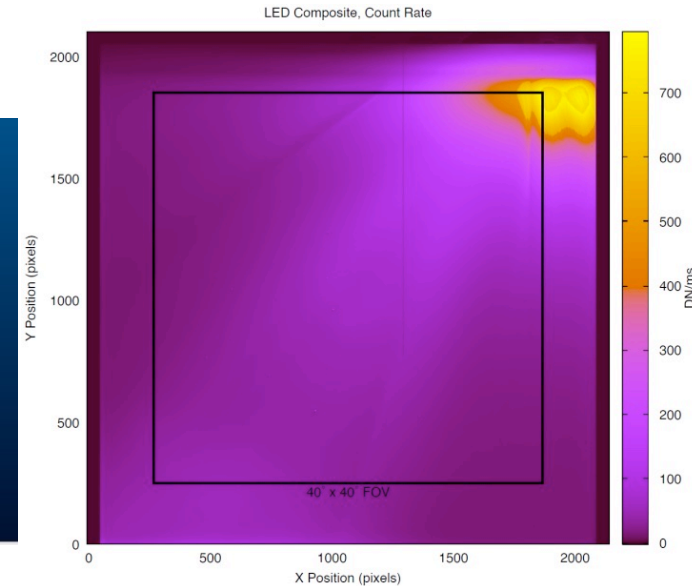
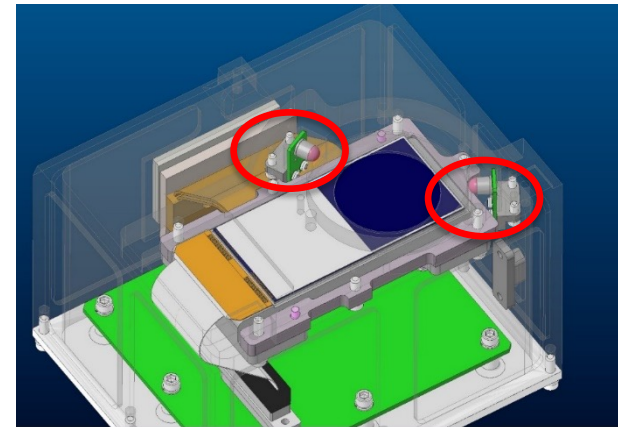
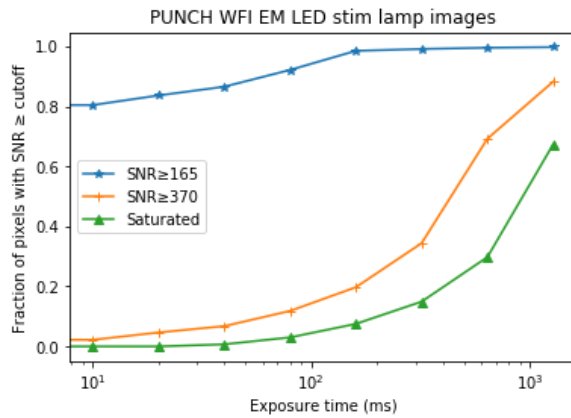
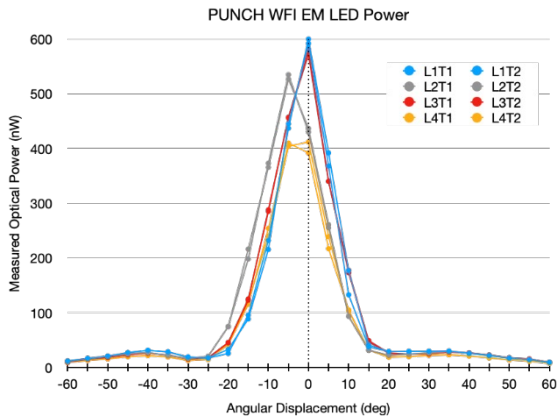
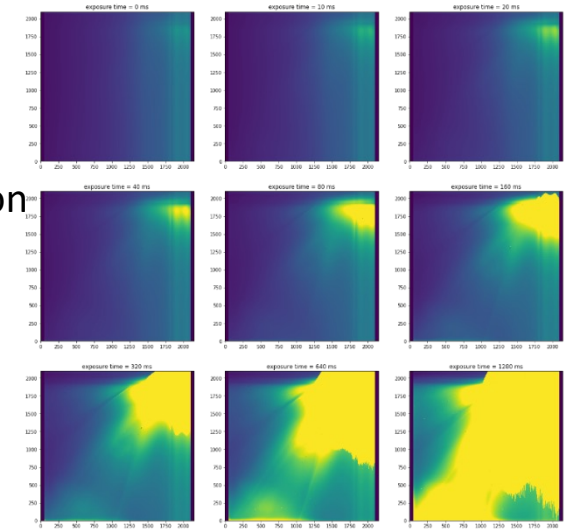
PUNCH 3 Science Meeting
July 6-7, 2023
Boulder, CO





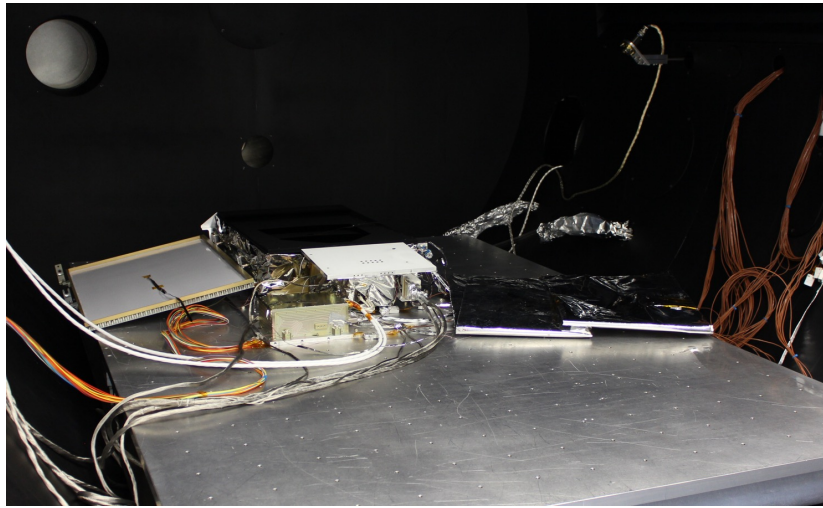
CCD STIM Lamp – EM Testing

- Requirement for Flat Field
- High heritage LED, emission peak near peak sensitivity of CCD
- Dual LEDs for more uniform illumination
- Multiple exposure integration times required for in-flight calibration due to non-uniform illumination
- EM unit validated during TVAC
- Exposure Pulse times 0 - 1.3sec (20mA LED current)
- **EM LED Functional testing complete**
 - LED light distribution curves repeatable
 - Range of exposure times allows for composite flat-field over full FOV

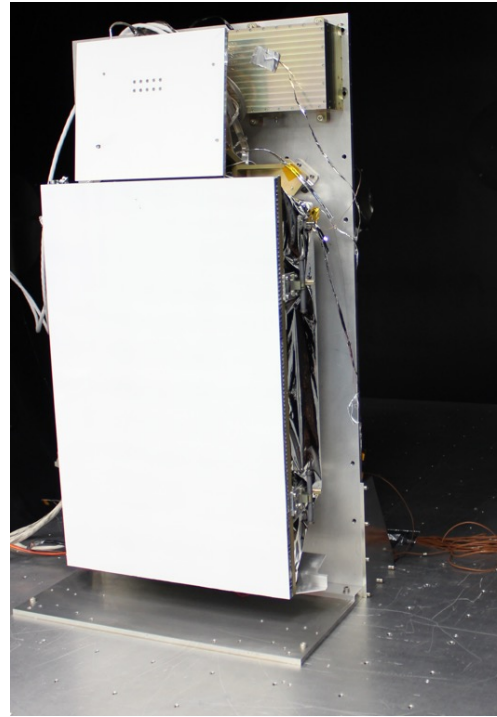




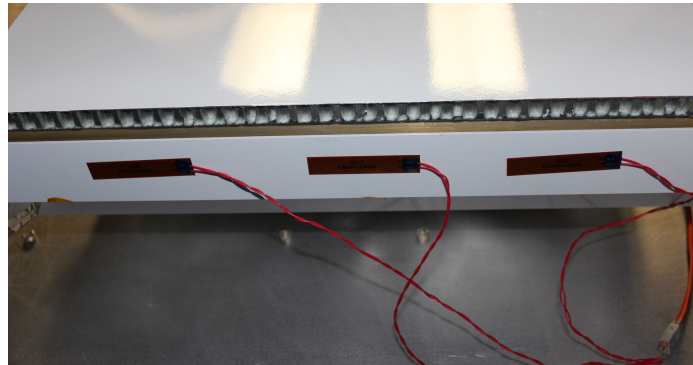
EM WFI TBAL/TVAC Test in SwRI DS8 Chamber



WFI with Door Open in Horizontal Configuration



WFI with Door Closed in Vertical Configuration

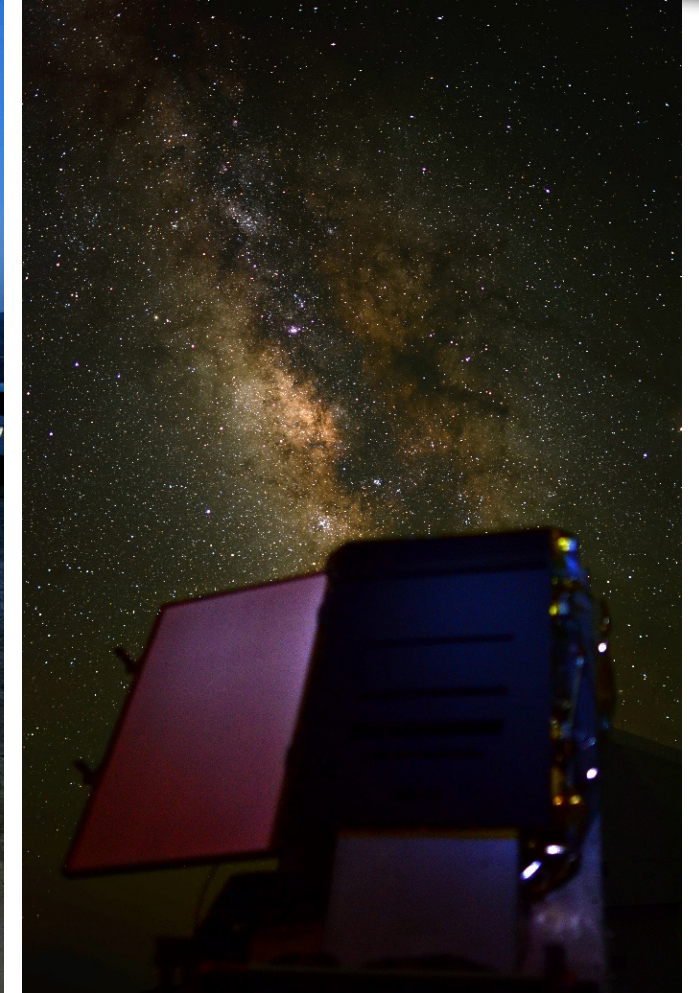
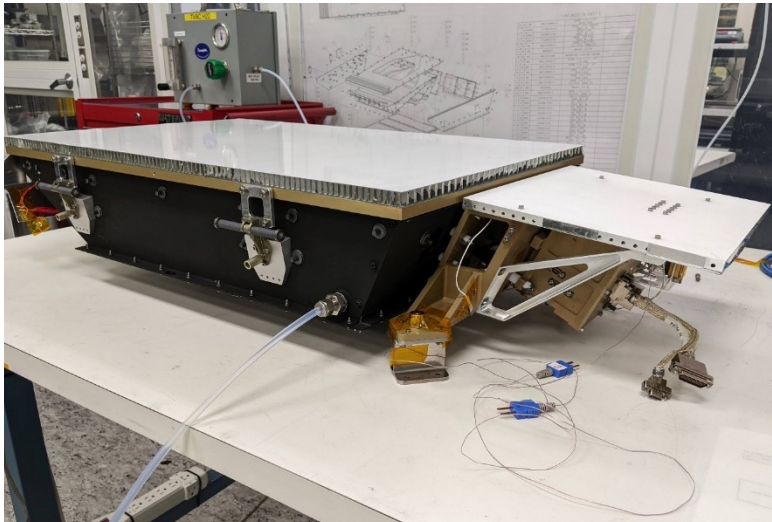


Patch Heaters Used to Simulate Solar Loading on WFI Solar Shade

- 20 Channels of thermal data collected, in addition to WFI internal PRT data
- Hot op, cold op and cold non op TBAL
- 8 TVAC cycles
 - 7 horizontal
 - 1 vertical to allow for door testing



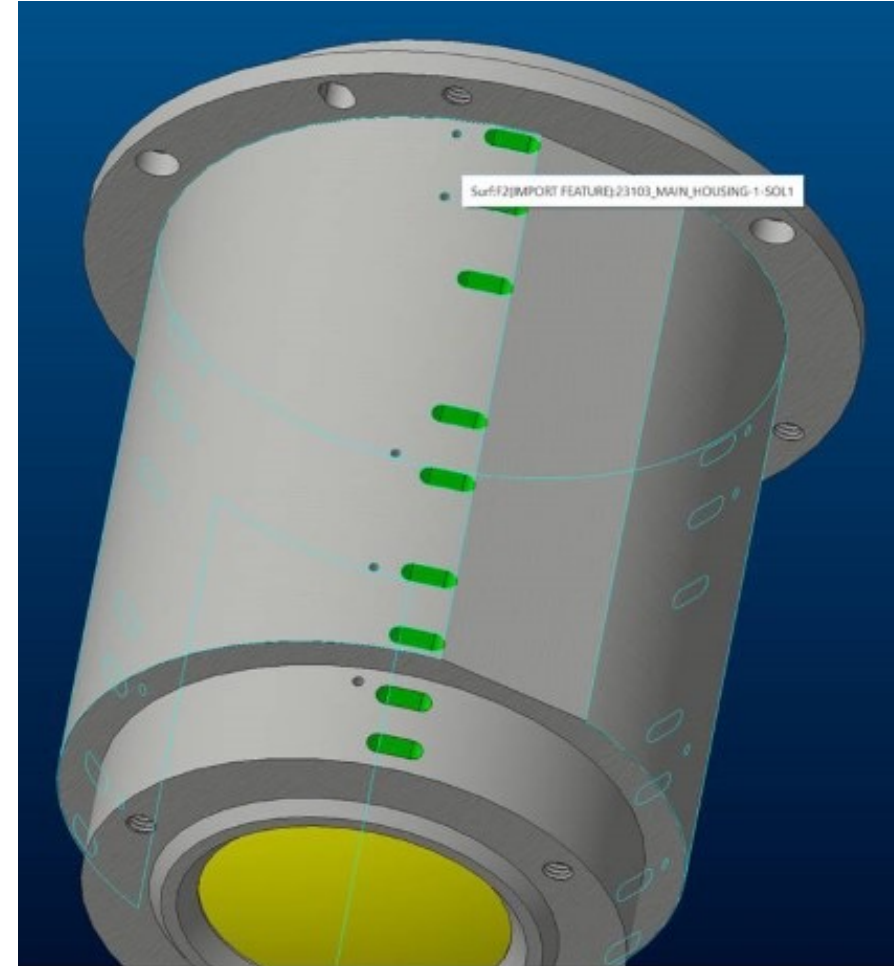
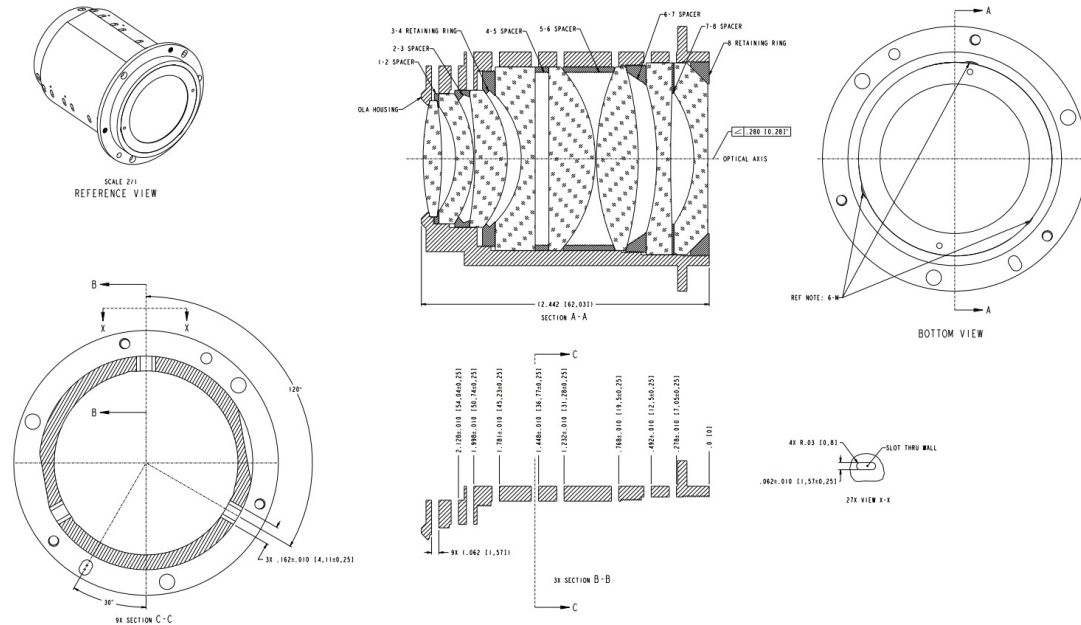
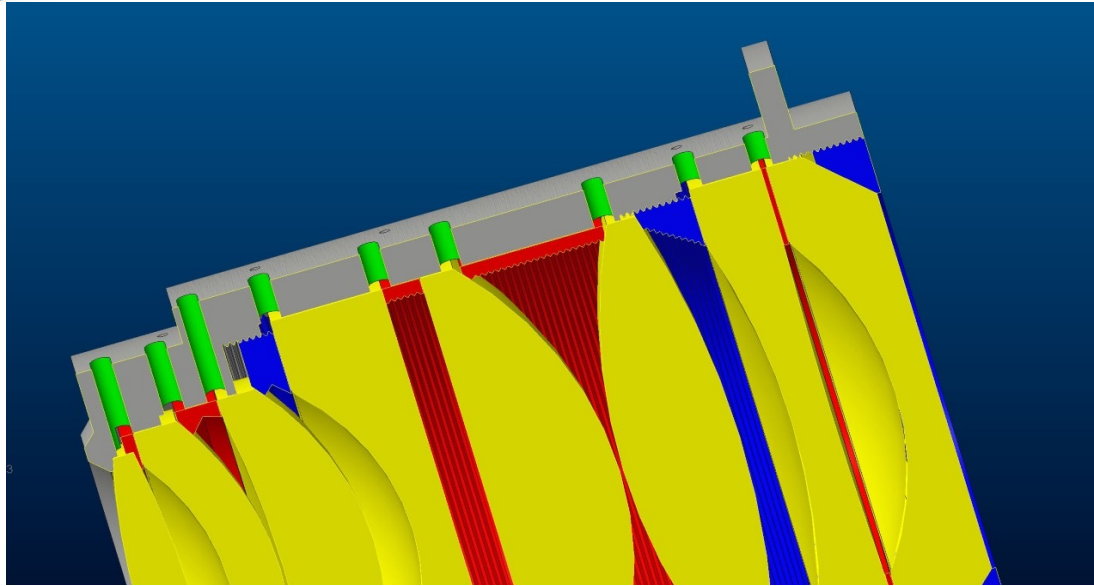
EM WFI Test Campaign Completed



EM WFI During Starfield Testing @ McDonald Observatory
(Analysis Underway)



WFI-1 Progress



OLA FM3 Housing Modifications



WFI-1 Door Progress



26401 PUNCH NO. 231033135

DRAWING MODEL NAME: 231033135-LATCH-CUP_FM

REFERENCE VIEW

SECTION A-A

REV		DESCRIPTION	DATE	APPROVED
A		REVISED IAW ECO 23103-138 S. SCHWARZ 2022-04-29	4/29/2022	AW
B		REVISED IAW ECO 23103-291 S. SCHWARZ 2023-03-24	03/27/2023	AW
C		REVISED IAW ECO 23103-304 S. SCHWARZ 2023-04-19	04/19/2023	AW

AR	1	-	-	-	-	NITRONIC 60 PER AMS 5848
-91 QTY	FIND NO	CAGE CODE	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION	

3. REMOVE ALL BURRS AND SHARP EDGES EQUIVALENT TO R.02 [0.5] MAX.

2. ALL DIMENSIONS ARE IN INCH [mm] UNITS.

1. INTERPRET DRAWING IAW ASME Y14.41-2012, Y14.5-2009 & Y14.100-2017.

NOTES: UNLESS OTHERWISE SPECIFIED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		CONTRACT 80GSFC18C0014		SRI SOUTHWEST RESEARCH INSTITUTE SAN ANTONIO, TEXAS	
DIMENSION	TOLERANCE	DATE	BY	DATE	BY
Ø .107 THRU TAP 6-32 UNC-2B THRU	± .010	2/14/2022	CHK /s/ Glenn Laurent	2/14/2022	
Ø .26 ± .05	± .005	2/14/2022	CHK /s/ AJ Wilson	2/14/2022	
Ø .36	± .010	2/21/2022	CHK /s/ Charles Tandy	2/21/2022	
Ø .194 ± .010	± .005	2/14/2022	CHK /s/ Keith Smith	2/14/2022	

WFI Latch Kickoff Spring Plunger Procured

WFI Latch Ball Fabricated

Latch Cup Fabrication