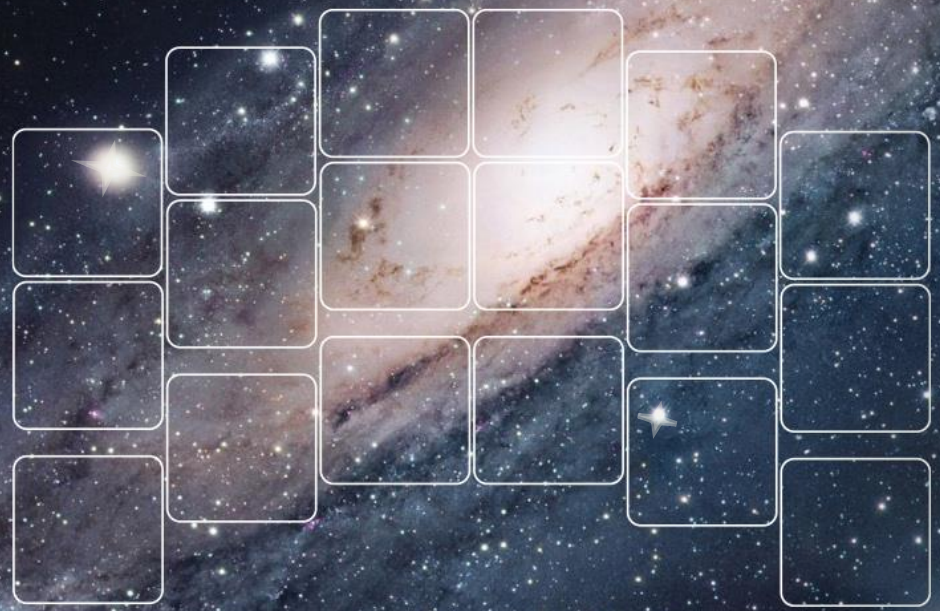
NANCY GRACE ROMAN SPACE TELESCOPE



NASA

BAE SYSTEMS

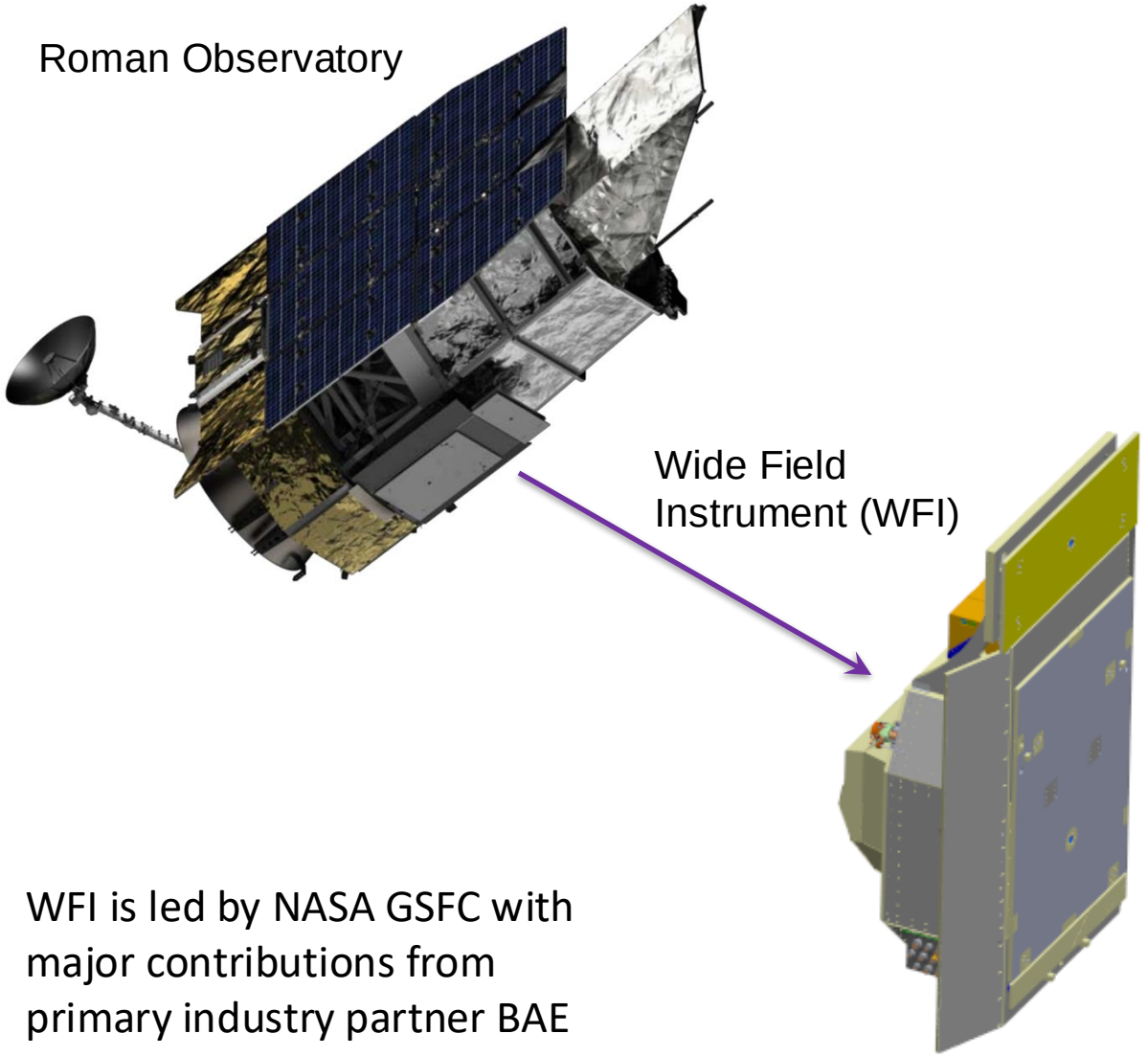
WFI Pre-Ship Review and Delivery Update

Roman Community Forum
08-28-2024

WFI Scientist	*Joshua Schlieder*
WFI Deputy Scientist	*Ami Choi*
WFI I&T Scientist	*Eric Switzer*

WHAT IS THE ROMAN WIDE FIELD INSTRUMENT (WFI)?

Roman Wide Field Instrument (WFI)



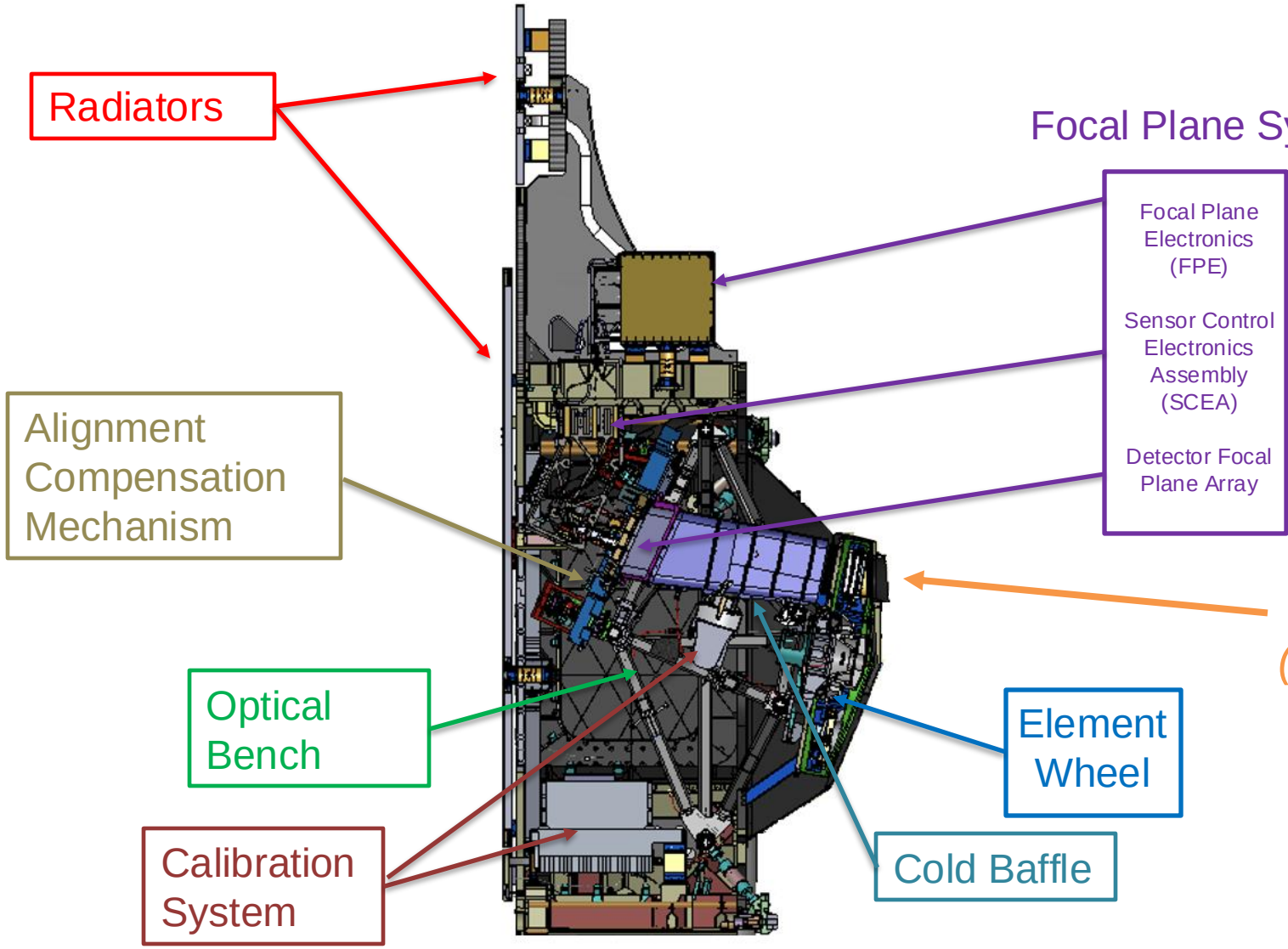
WFI is led by NASA GSFC with major contributions from primary industry partner BAE Systems

Instrument Overview

- Focal plane array of 18 4k × 4k detectors
  - Teledyne H4RG-10 detectors with 10 µm pixel pitch
  - Large FOV – 0.8 x 0.4 deg (0.281 deg^2, excluding gaps)
  - 300,000,000 pixels with 0.11”/pix
  - Image stability: 1.0 nm RMS wave front error (WFE) variation in 180 sec
  - Guide star sensing interleaved with science data collection
- Element wheel enables imaging and spectroscopy spanning 0.48 to 2.3 µm
  - 8 imaging filters
  - Prism and grism for full-field, slitless spectroscopy
  - Blank position for darks, flat fields, and other calibrations
- Internal relative calibration system
- Instrument is passively cooled

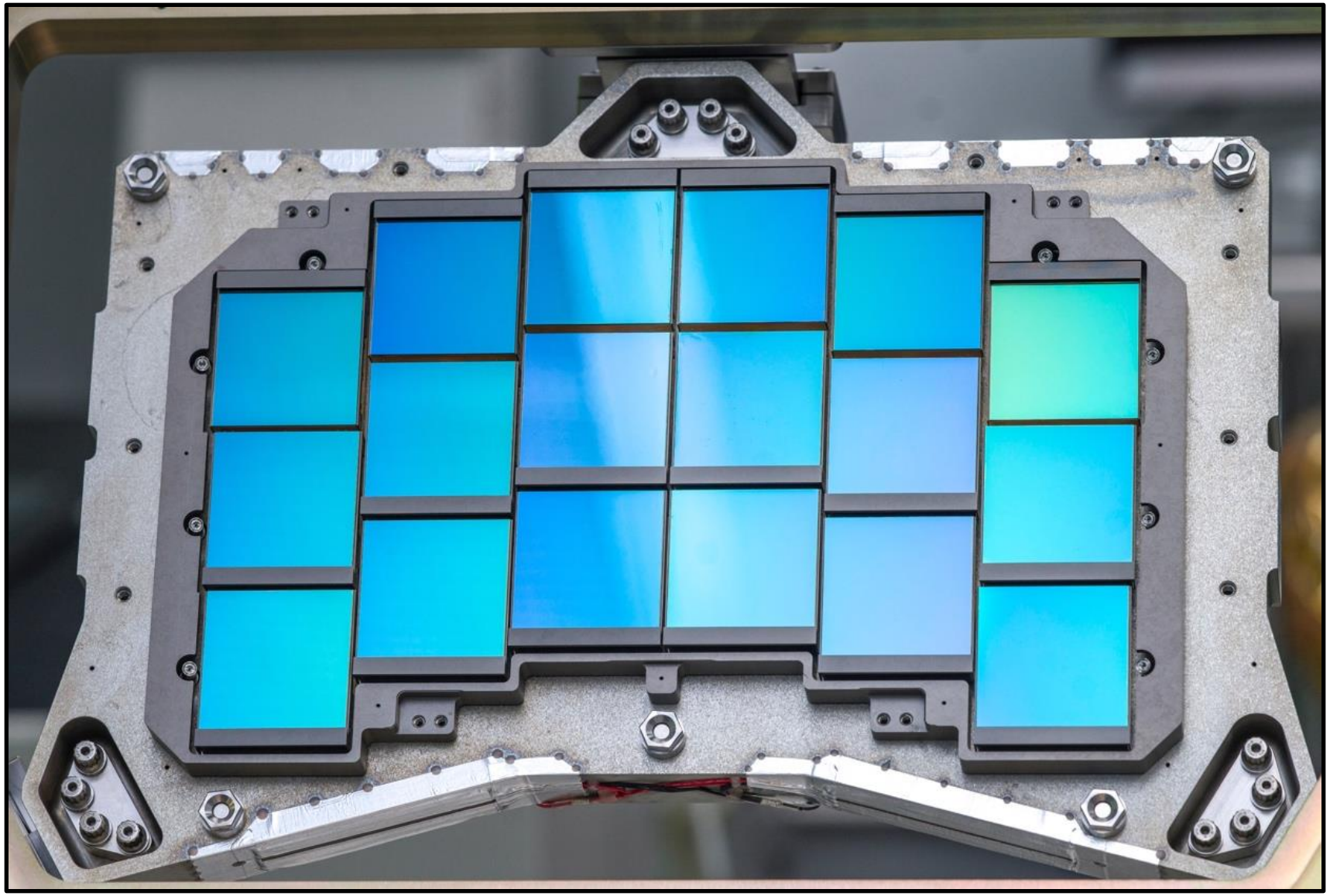
https://roman.gsfc.nasa.gov/science/WFI_technical.html

Wide Field Instrument – Key Subsystems



Not shown here:
Instrument and Mechanism Control Electronics located in spacecraft bus

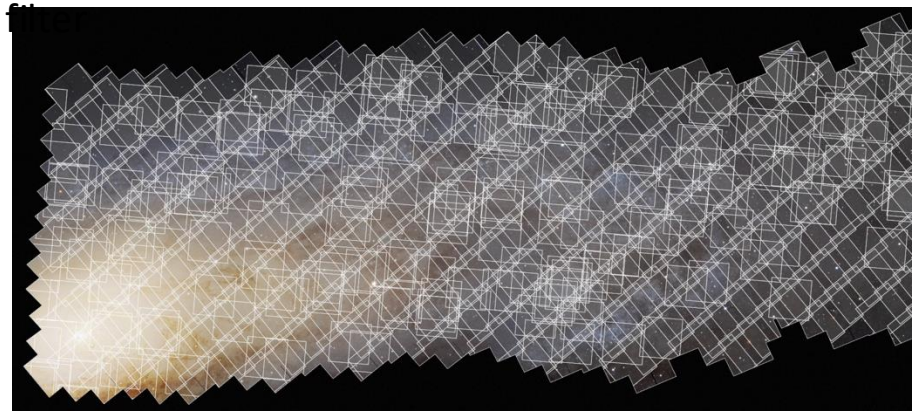
WFI Focal Plane Array



Roman + WFI – Built for Surveys

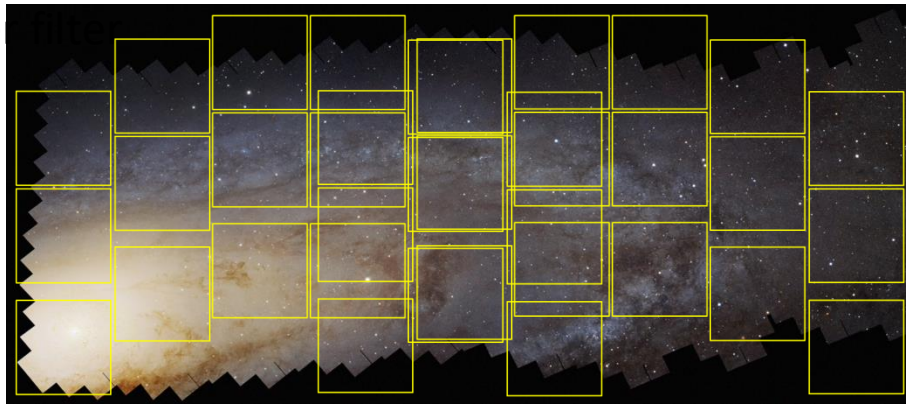
- **The power of Roman for surveys is not *only* in the WFI field-of-view**
  - **Very efficient observations from L2**
  - **Rapid slew and settle**
  - **Well understood and stable PSF**
  - **Excellent flux calibration**
- **Larger FOV + efficient and stable operations yields *survey speeds ~1000x faster than Hubble***
- **The WFI enables Roman's next generation survey science**

HST PHAT survey of M31 - >400 observations per filter



(Dalcanton et al. 2012)

Roman WFI covers similar sky area in 2 observations per filter



PURPOSE OF THE WFI PRE-SHIP REVIEW (PSR)

WFI PSR – Format, Goals, and Results

- WFI PSR was held at BAE Systems Inc. in Boulder, CO from July 30 to August 1 , 2024
  - Two days of presentations to a Standing Review Board with a broad range of expertise across engineering and science, followed by a half-day of Review Board discussion and outbrief to the WFI team

- The goal of the PSR was to show that WFI meets performance and other requirements and is ready to be shipped to NASA Goddard for payload level integration and tests
  - Data from environmental and other test campaigns used to verify instrument requirements

- **Bottom Line Up Front -- WFI passed PSR with compliments from the Review Board!**

WFI TEST CAMPAIGNS AND SCIENCE DATA COLLECTION

WFI Environmental Test Campaigns

- **September to November 2023 – Thermal Vacuum Test #1**
  - Establish instrument performance baseline in flight like environment
  - **Verify some requirements**
  - **Risk reduction tests to prepare for TVAC2**

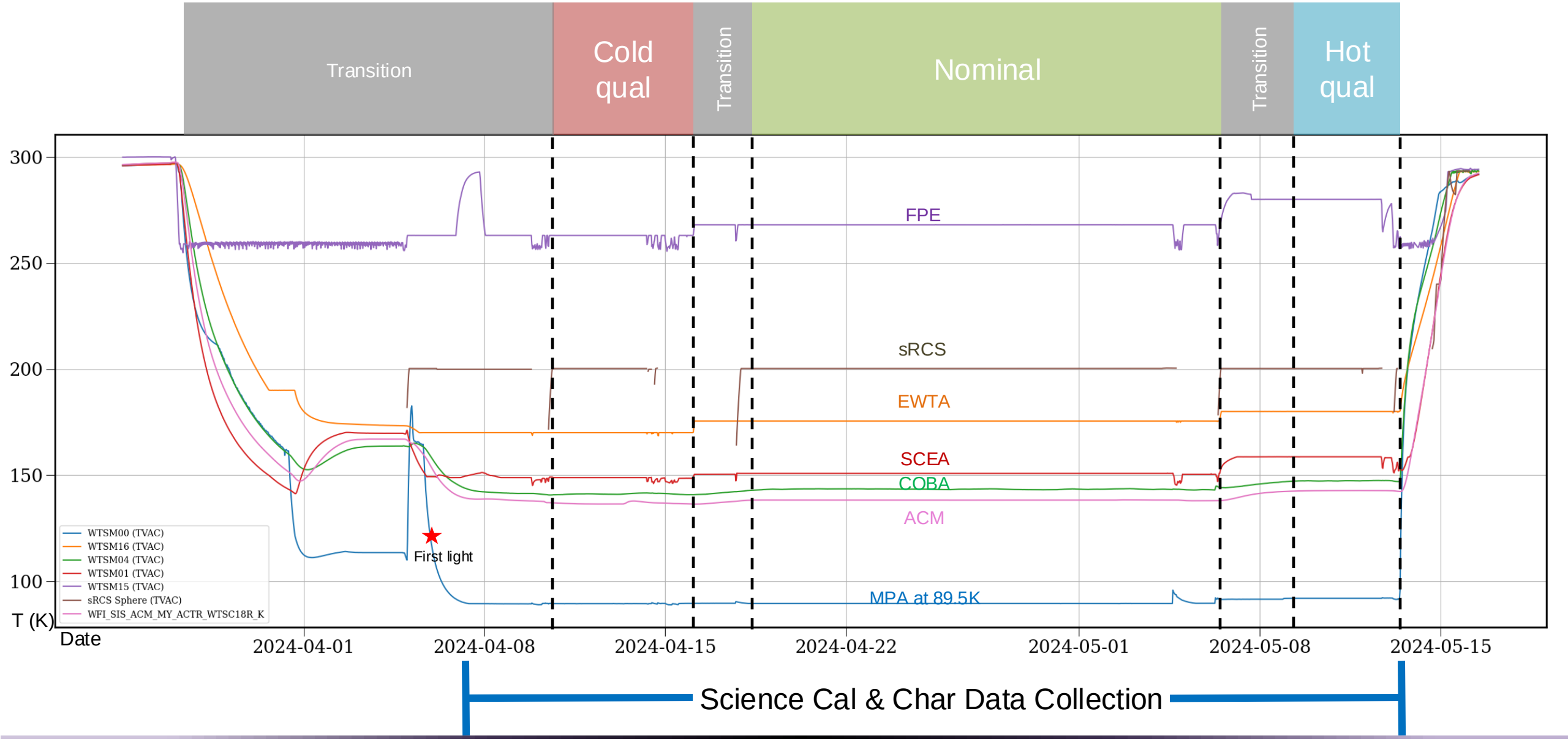
- **January and February 2024 – Vibration and Acoustic Tests**
  - Simulate launch environment

- **March to May 2024 – Thermal Vacuum Test #2**
  - Verify TVAC1 Baseline
  - **Run-for-the-record tests to verify requirements**
  - **Science characterization and calibration tests**

- **June 2024 – EMI/EMC Test**
  - Electromagnetic interference and compatibility tests

WFI+Telescope Simulator Moving into the Vacuum Chamber

TVAC2 Thermal Timeline



Science Data Collection went Very Well during WFI TVAC2

- **Goals:**
  - Verify WFI meets requirements and collect data to produce science calibration reference files
  - Establish instrument cryo performance for science calibration and characterization
  - Perform risk reduction tests to further prepare for flight

- **Types of Science Data obtained:**
  - Focal Plane System performance
  - Thermal backgrounds, element blocking, and stray light characterization
  - Optics characterization for science – Filters, Grism, and Prism
  - Calibration system performance and detector calibration
  - Guide window operations and performance
  - Risk reduction tests

- **461 data collections performed during TVAC2 – total data volume ~270 TB**

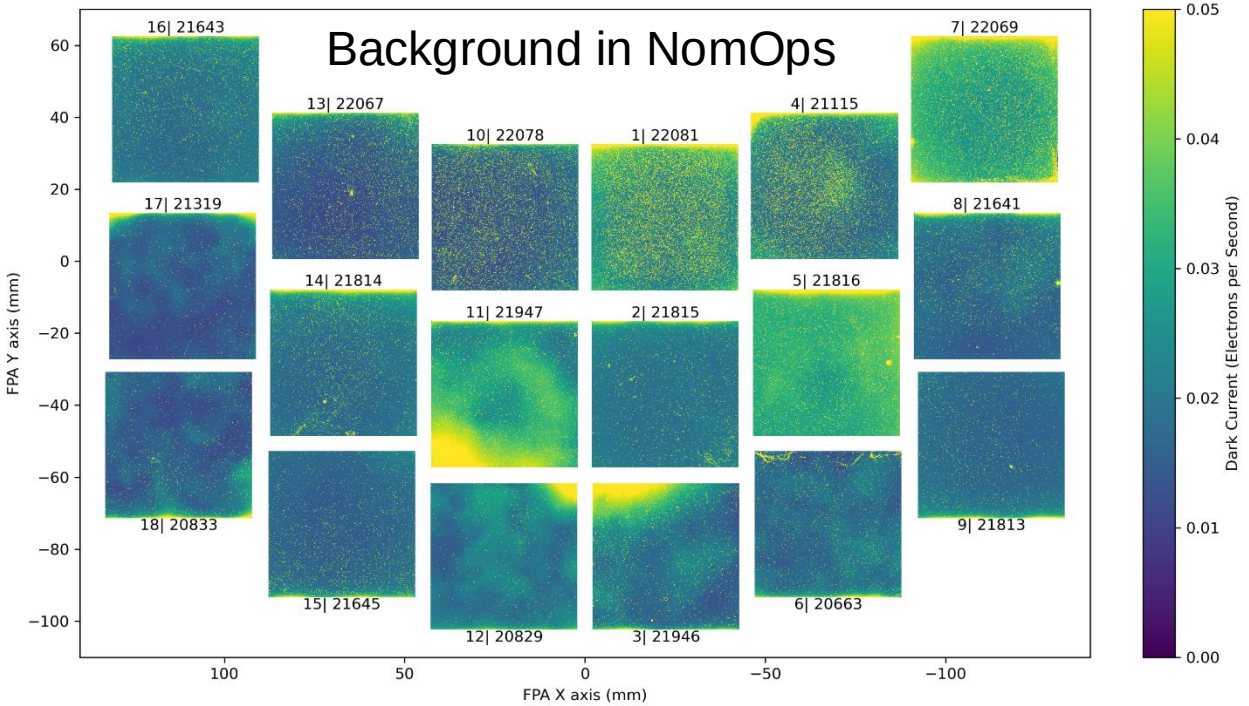
- **TVAC2 test results were presented at PSR to demonstrate compliance with requirements**

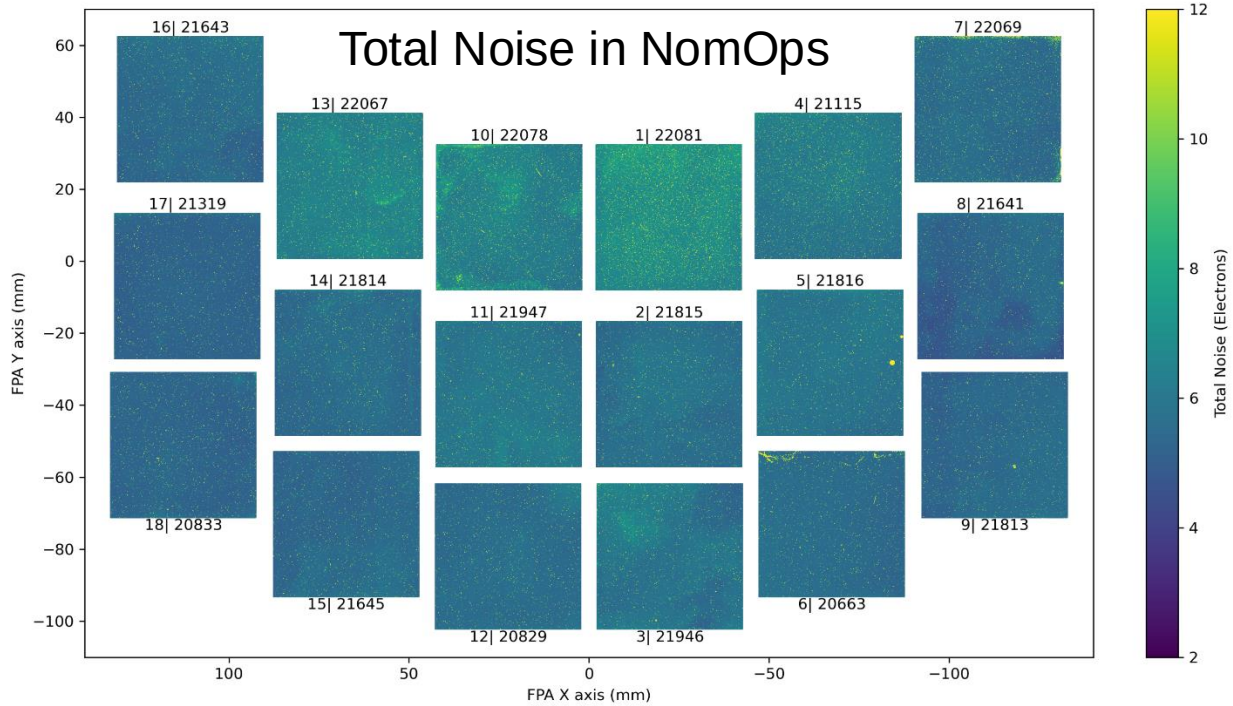
WFI PSR SCIENCE RESULTS SUMMARY

FOCAL PLANE SYSTEM (FPS)

FPS Dark Current and Noise

- All detectors meet requirements - Dark current (thermal background) and noise are mostly unchanged since TVAC1





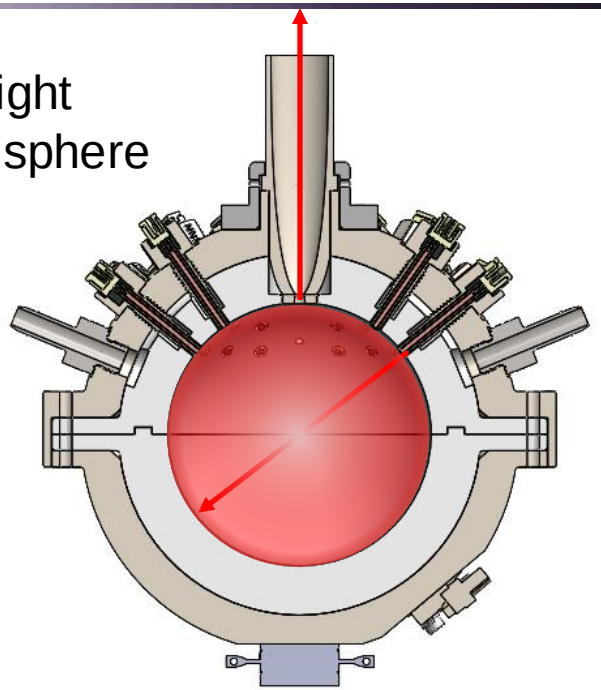
Comply with requirement – Background < 0.045 e^-/pix/s

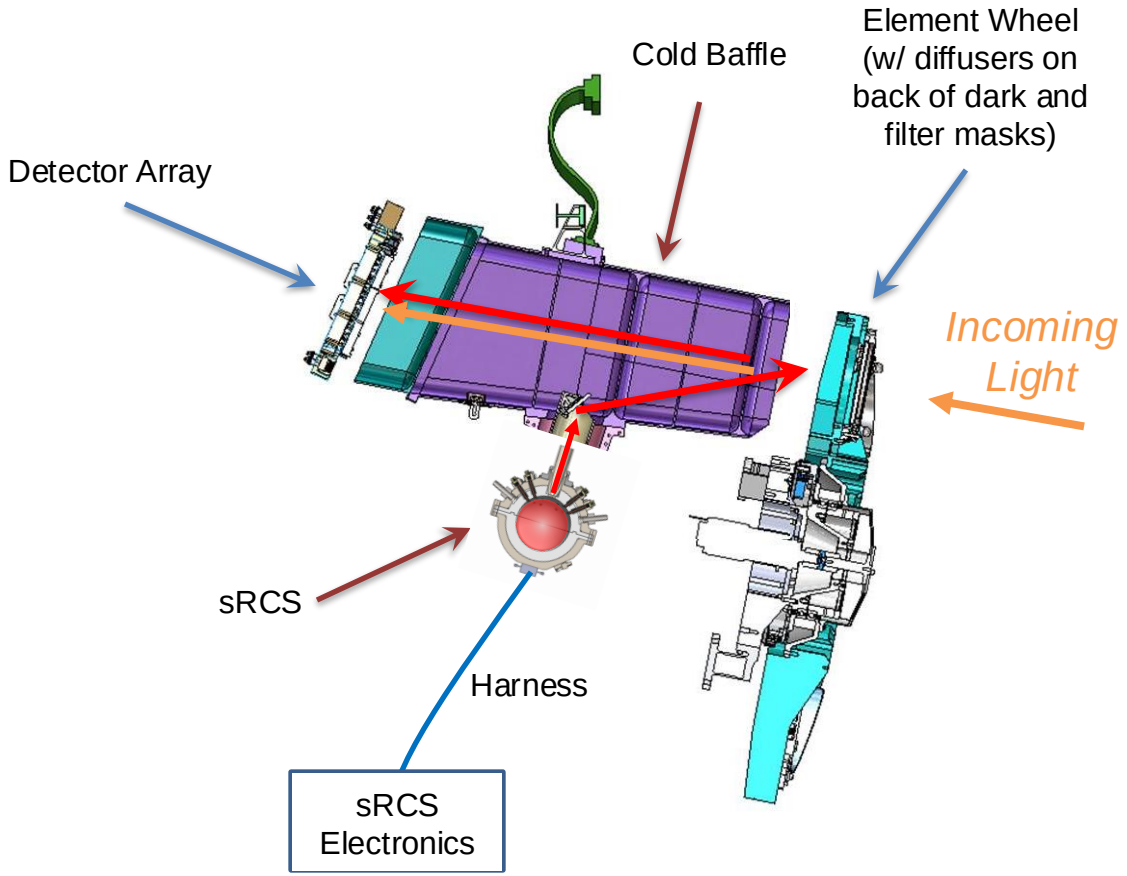
Comply with requirement – Total noise < 7.5 e^-

SIMPLIFIED RELATIVE CALIBRATION SYSTEM (SRCS)

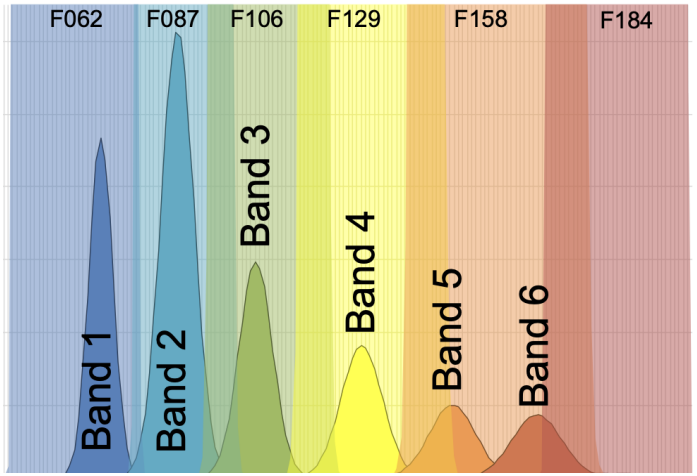
Simplified Relative Calibration System (sRCS) Description

sRCS light source sphere





sRCS LED output compared to filter bandpasses



sRCS Sphere has Side A & B. Each side has:

- 2 banks of 6 LEDs (2 LEDs per band)
- 2 photodiodes, InGaAs and MCT
- Enables multiple modes of detector calibration using flat fields

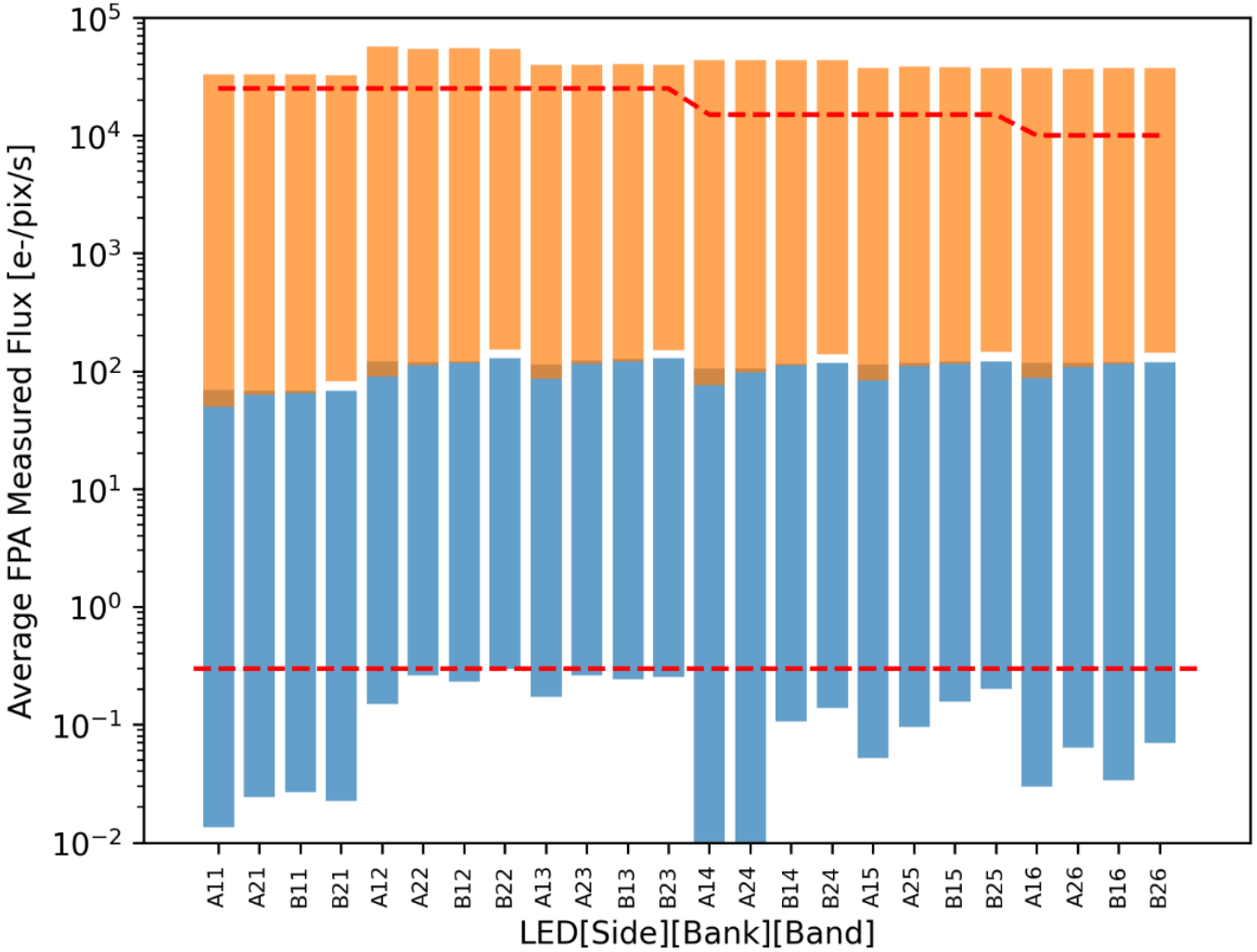
TVAC2 showed that the sRCS will enable the calibration of WFI on-orbit

- **sRCS performance has been extensively characterized. The system performs well and will enable on-orbit calibration of the WFI**

- **It can flatfield every pixel in the detector array over ~5 orders of magnitude in flux in 6 distinct wavelengths bands.**
  - This capability will be the workhorse use case of the sRCS on-orbit, used for a slew of calibration programs.

- **It can enable multiple techniques for on-orbit flux-dependent non-linearity (FDNL) calibration to unprecedented accuracy (our most stringent requirement)**
  1. Lamp-on, lamp-off (LOLO) is enabled in all 6 bands by the ability to add a tunable pedestal on top of a sky scene; this cannot be verified by test on the ground so it is not used as a verification method
  2. Combinatorial flux addition (CFA) was demonstrated in ~5 out of 6 bands (on side B). This is much harder to verify than LOLO, but we focused on it as a stress case.
  3. An additional calibration method is enabled in all 6 bands by combining response of photodiodes embedded in the light source sphere and response of the detectors. Development of this approach continues using TVAC2 data.

sRCS LED Dynamic Range



Max flux requirements

Min flux requirement

sRCS can deliver the required range of illumination to the MPA; comply with requirement

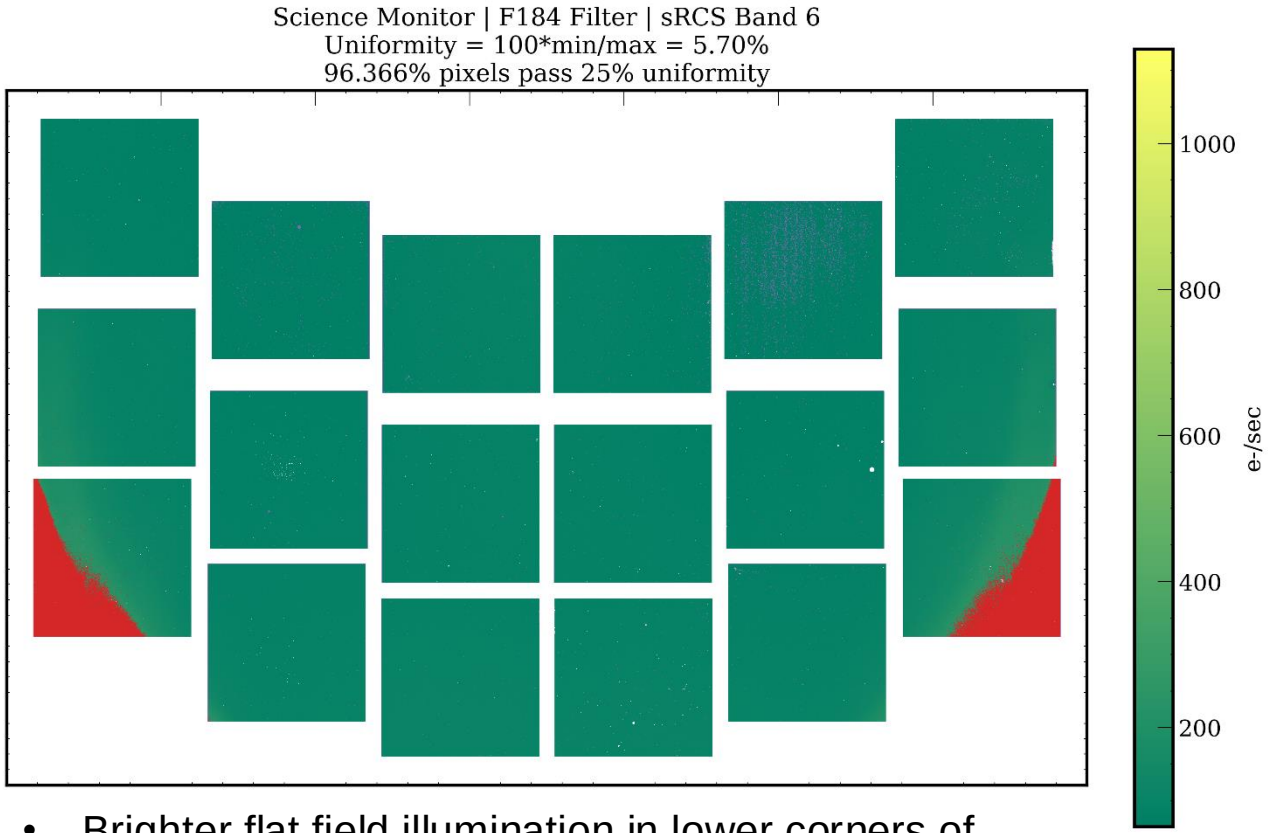
sRCS Flat Field Uniformity

- **sRCS illumination uniformity is the min/max of illumination, needed for good flatfields**

sRCS LED Band	Dark Uniformity (Req >50%)	Pixels Passing 50% Dark Uniformity	LOLO filter	LOLO uniformity (Req >25%)	Pixels Passing 25% LOLO Uniformity
1	73.57	>99.9	F062	70.04	>99.9
2	75.4	>99.9	F087	71.54	>99.9
3	75.25	>99.9	F106	65.13	>99.9
4	75.16	>99.9	F129	67.42	>99.9
5	76.22	>99.9	F158	63.01	>99.9
6	76.51	>99.9	F184	5.7	96.4

All numbers in %

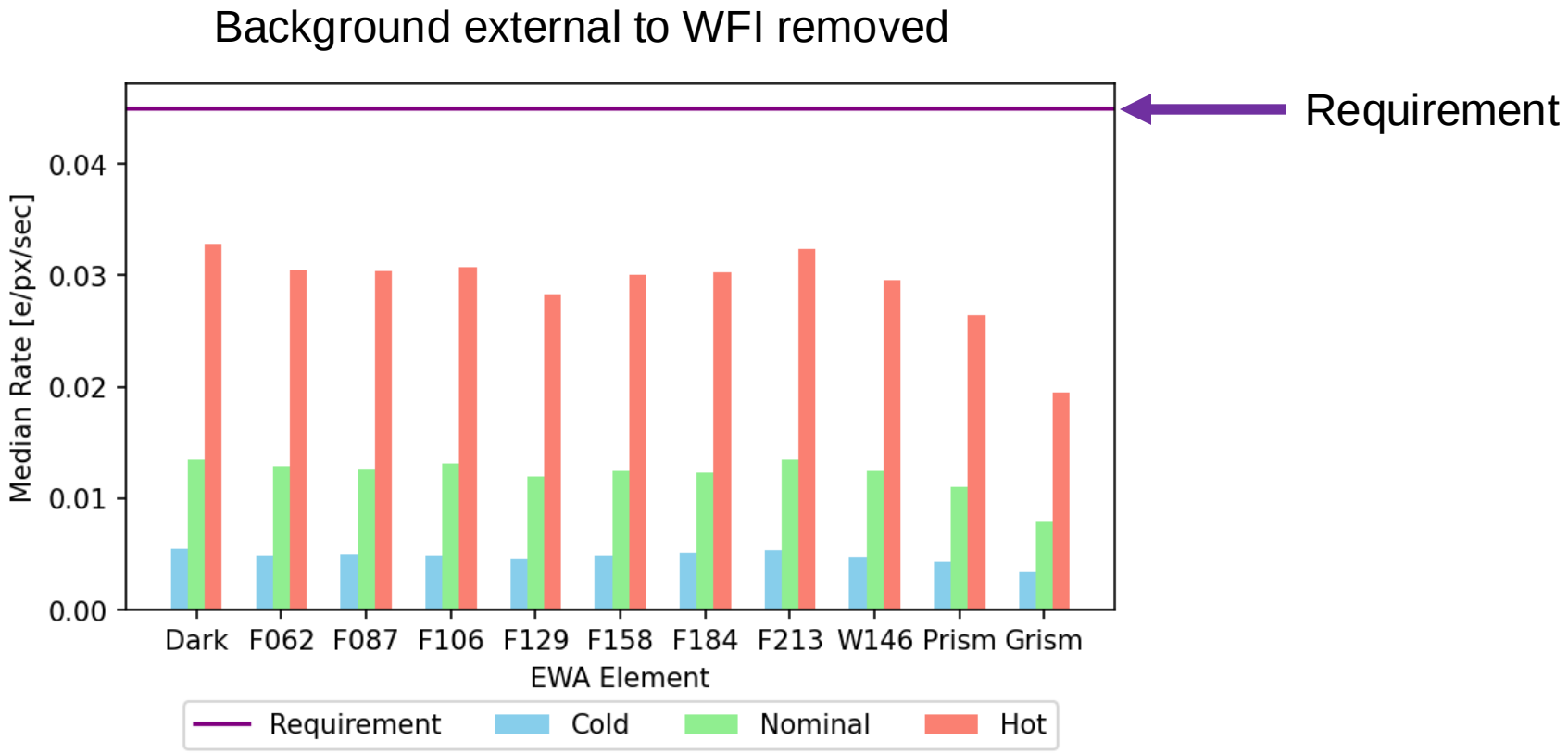
sRCS uniformity is excellent; minor deviation in LOLO mode in LED band 6 is acceptable



- Brighter flat field illumination in lower corners of detector array only in LOLO Band 6/F184 filter
- Pixels in red do not pass requirement, out-of-band LED light reflects off filter coating and scatters back to detectors

BACKGROUNDS

Instrument Internal Thermal Background Results



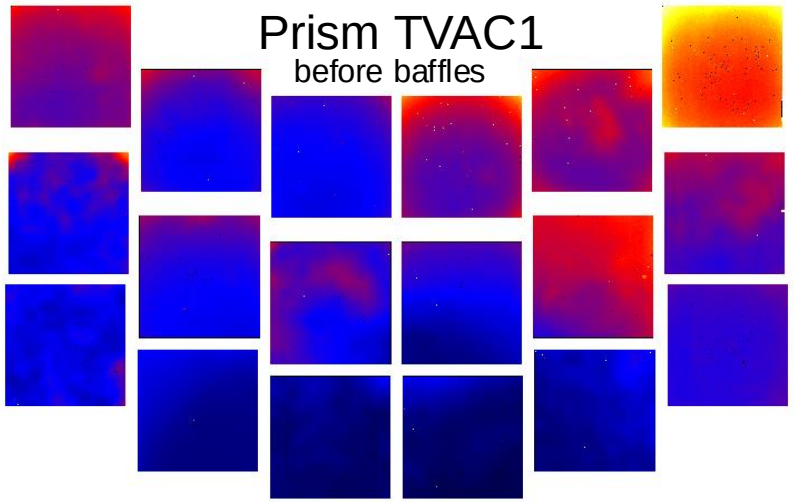
WFI internal thermal background requirement is met with margin at all thermal plateaus

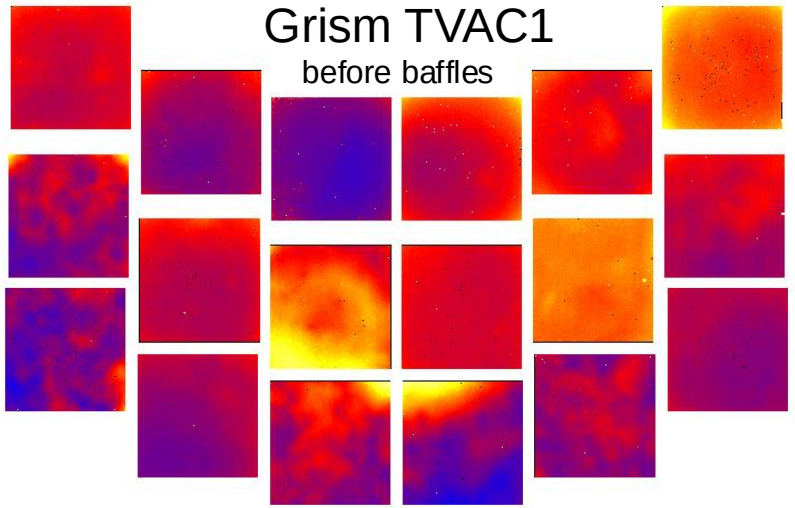
Observatory Scene Thermal Background

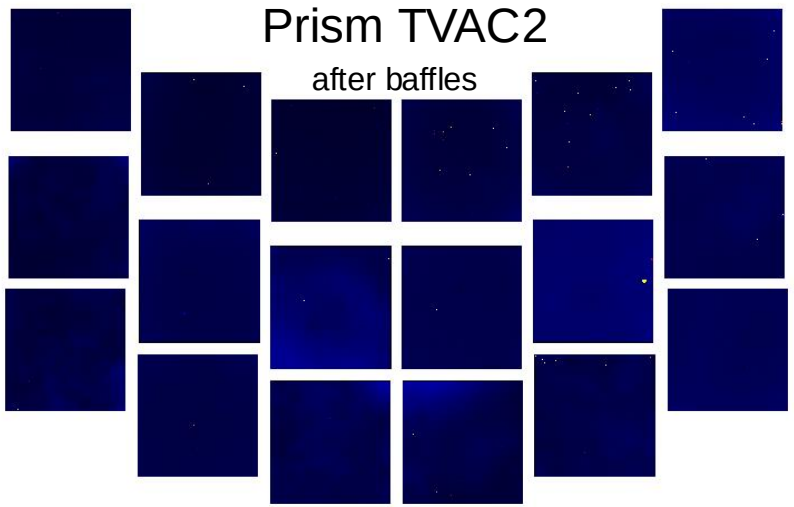
- During TVAC1 we saw unexpectedly high thermal leaks associated with the prism and grism
- Stray light model was correlated using TVAC1 data; likely proximate cause identified as leaks around outer edges of optics that do not carry bandpass coatings
- Observatory-level predictions showed unacceptable levels of structured stray light caused by these thermal backgrounds
- The WFI team worked with the observatory team to design baffle mitigations that were successfully implemented between TVAC1 and TVAC2.
- TVAC2 testing showed dramatic improvements. New observatory-level predictions show acceptable levels of background and elimination of structured stray light patterns that would impact surveys

Baffle mitigation for grism/prism was highly successful and TVAC2-correlated performance predicts are acceptable for science.

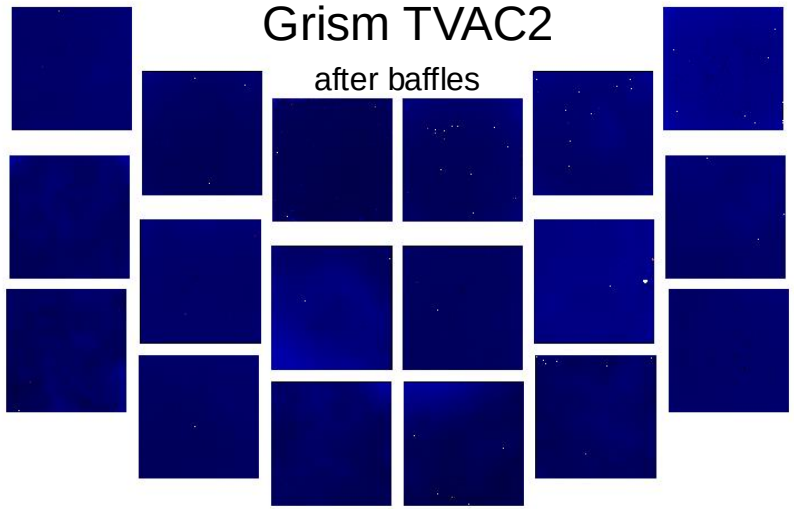
Observatory Scene Thermal Background – Prism and Grism







~7x improvement



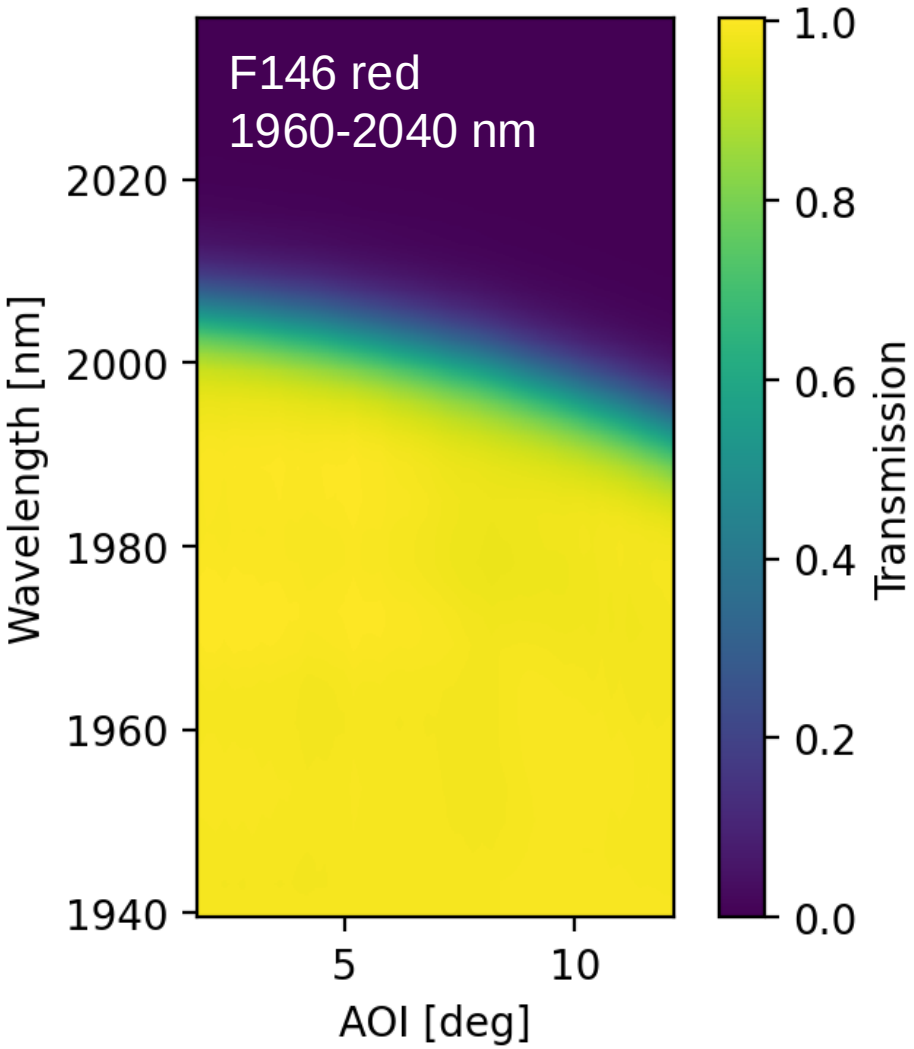
~7x improvement

FILTER, GRISM, AND PRISM CHARACTERIZATION

Filter Bandpass Edge Measurements

- Sweep narrowband light over the filter edge, measure transmission relative to pass region across the field.
- **Analysis Summary: compress field dependence of bandpass edge into mean pupil Angle of Incidence (AOI).**
- **Measure edge variation as a function of location in focal plane array**

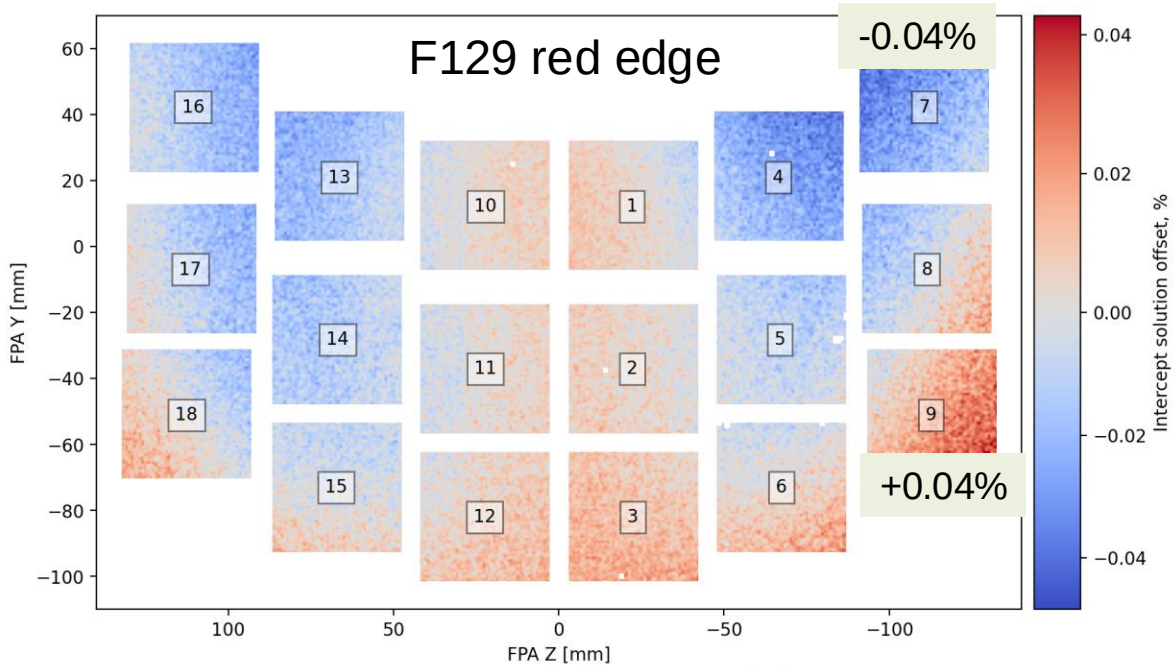
Bandpass edges comply with requirements for all filters, F213 red edge verified using witnesses.

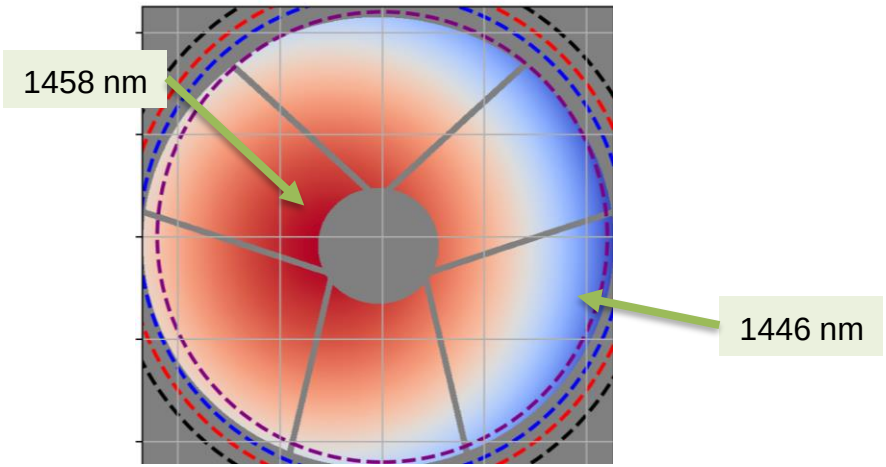


Filter Bandpass Edge Knowledge

- **Performed with telescope simulator diffuser – flat field wavelength sweeps across bandpass edges**
- Also measured pupil transmission across bandpass edges using focus-diverse phase retrieval technique as a cross-check
- **TVAC2 bandpass edge knowledge characterization leads to closure of long-standing mission risk linked to photometric accuracy**

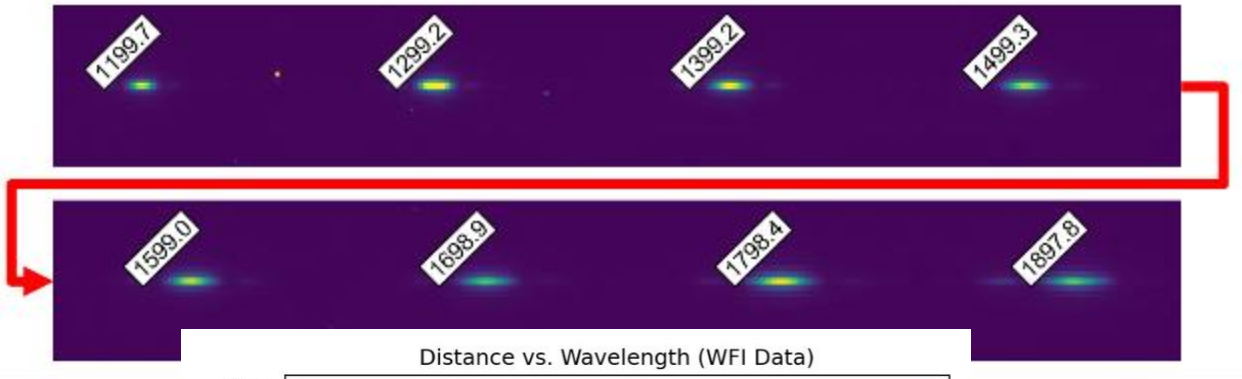
Filter model describes edges to ≤0.05% knowledge, complies with requirements. Allows measurement of edge gradient across physical extent of filter and change in edge with AOI



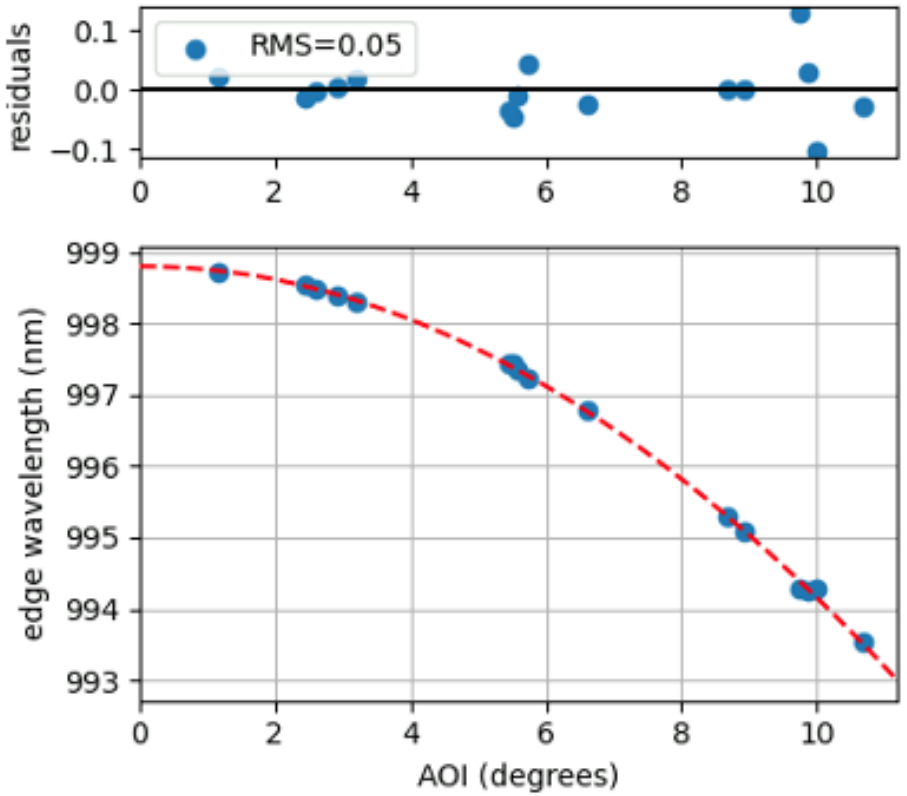


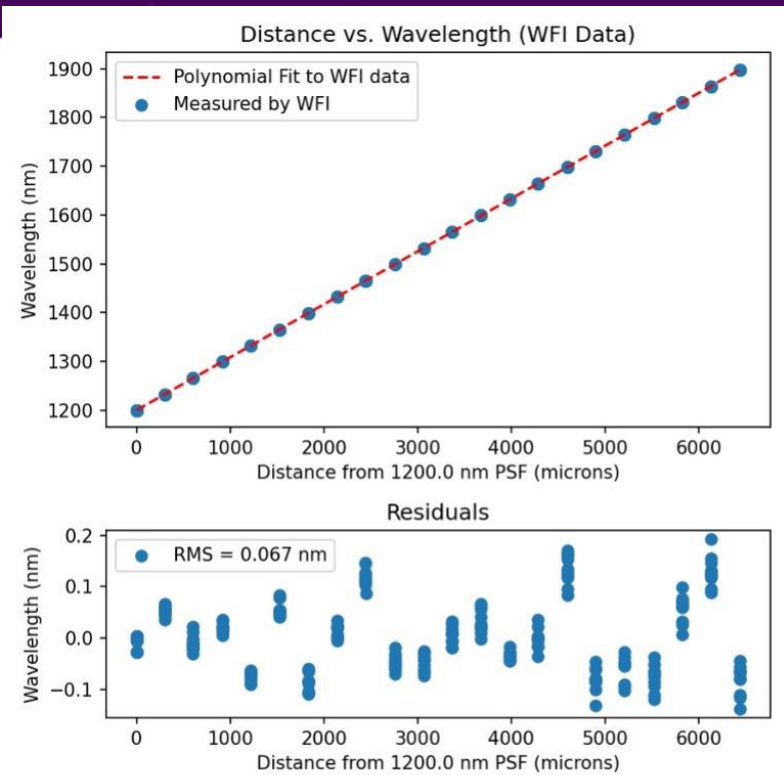
Grism Blue Edge and Dispersion

- Measured the dispersion and bandpass edges of the Grism and Prism during TVAC2
- Used for requirements verification at PSR, updates to optical models, and calibration pipeline inputs



Grism Blue Edge across FOV





Grism dispersion data and polynomial fit

WFI DELIVERY, HIGHER LEVEL I&T, AND FLIGHT

WFI was Shipped and Delivered to NASA Goddard in Early August

Prep for shipment from BAE Systems, Boulder CO

WFI was Shipped and Delivered to NASA Goddard in Early August

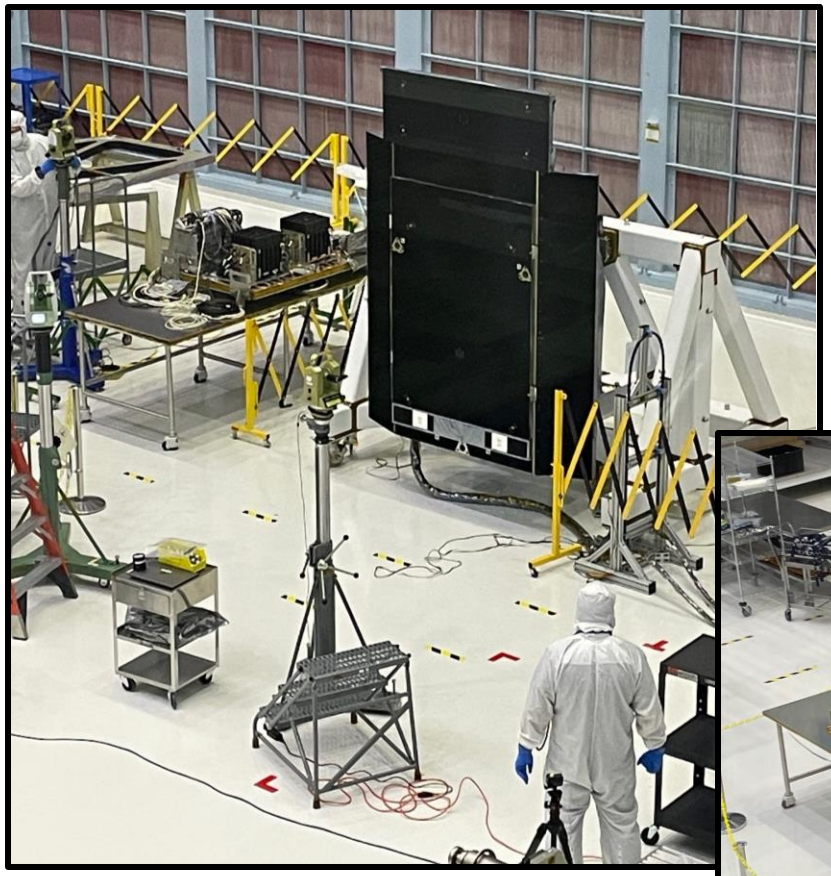
Shipment from BAE Systems, Boulder CO

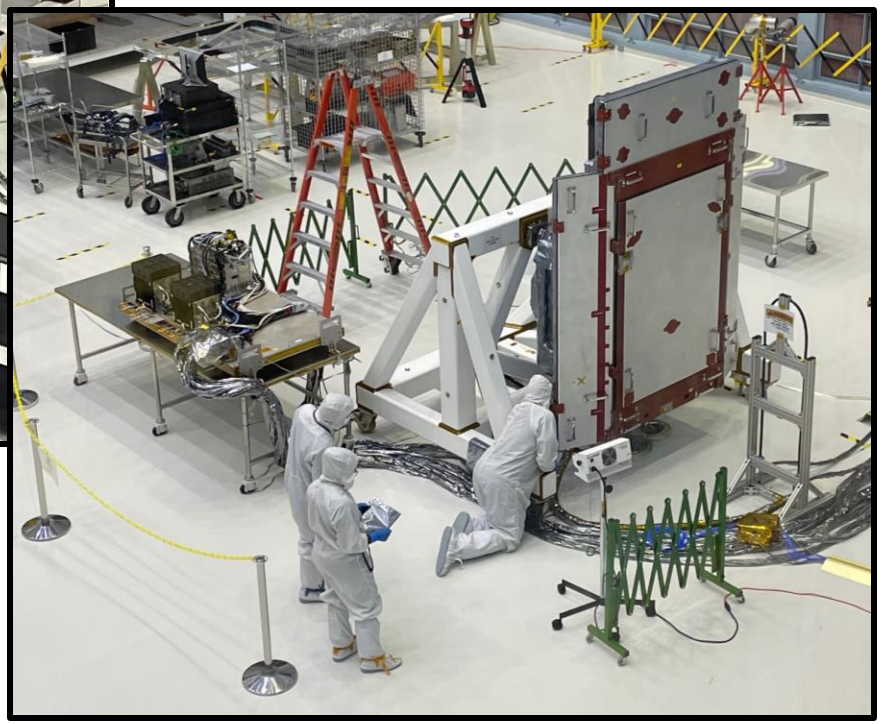
WFI Was Shipped and Delivered to NASA Goddard in Early August

Arrival at NASA Goddard, Greenbelt MD

WFI was Shipped and Delivered to NASA Goddard in Early August

- **The instrument has since undergone several post-ship tests**
  - Alignment/metrology measurements, stray light/light leak test, ambient functional test (in progress)





Science Analyses Post WFI-Delivery – The Road to Flight

- **Science stakeholders turning focus to generation of calibration reference files and other necessary imaging and spectroscopy pipeline inputs**
  - Multiple meetings established to focus on these topics and track plans and progress
  - Flowing into commissioning planning for flight calibration
  - WFI TVAC planning and execution experience flowing into plans for flight science commissioning and additional WFI tests at Space Craft and Integrated Payload Assembly (SCIPA) TVAC test
  - Calibration Working Group holds deeper discussion on TVAC data characterization and calibration and flow to flight calibration plan
- **Final science analysis results will be presented to science community in a series of proceedings and journal articles with all stakeholders contributing**

WFI PSR and Delivery Summary

- **Completed a highly successful campaign of WFI science performance characterization and calibration measurements throughout WFI environmental test campaigns**
- **WFI Science characterization and calibration requirements are either met or have acceptable waivers/paths forward, successfully cleared PSR**
- **WFI has been delivered to NASA Goddard for integration into the payload assembly**
- **TVAC2 data and analysis informs plans for multiple WFI sRCS and FPS trending tests at SCIPA level TVAC**
- **Stakeholders moving on to using TVAC2 data/verifications to generate calibration reference files, further develop flight calibration plans, and science pipeline development**

WFI Pre-Ship Review was a success, and the instrument is now at NASA Goddard for payload integration!