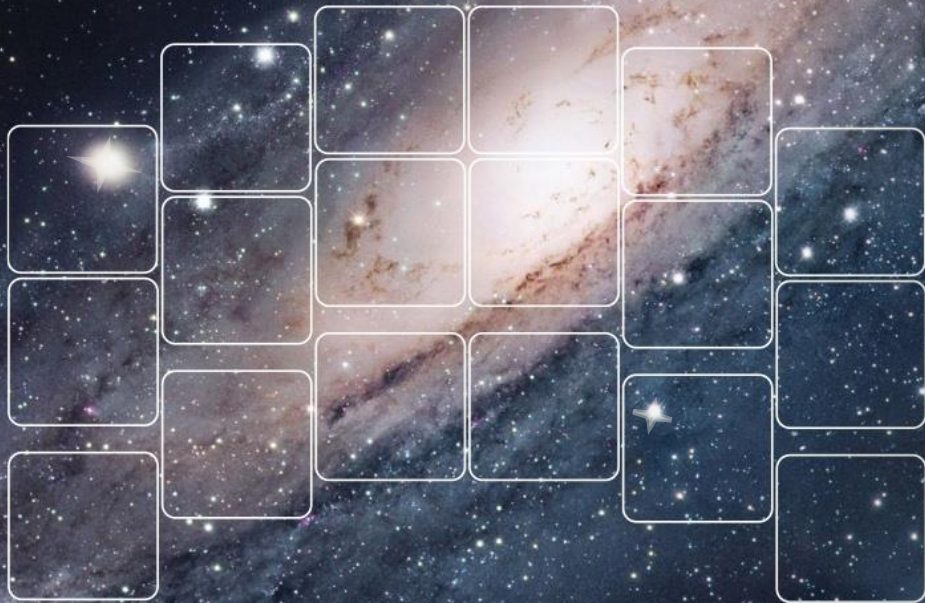




NANCY GRACE ROMAN



SPACE TELESCOPE

Roman Space Telescope Optical System:

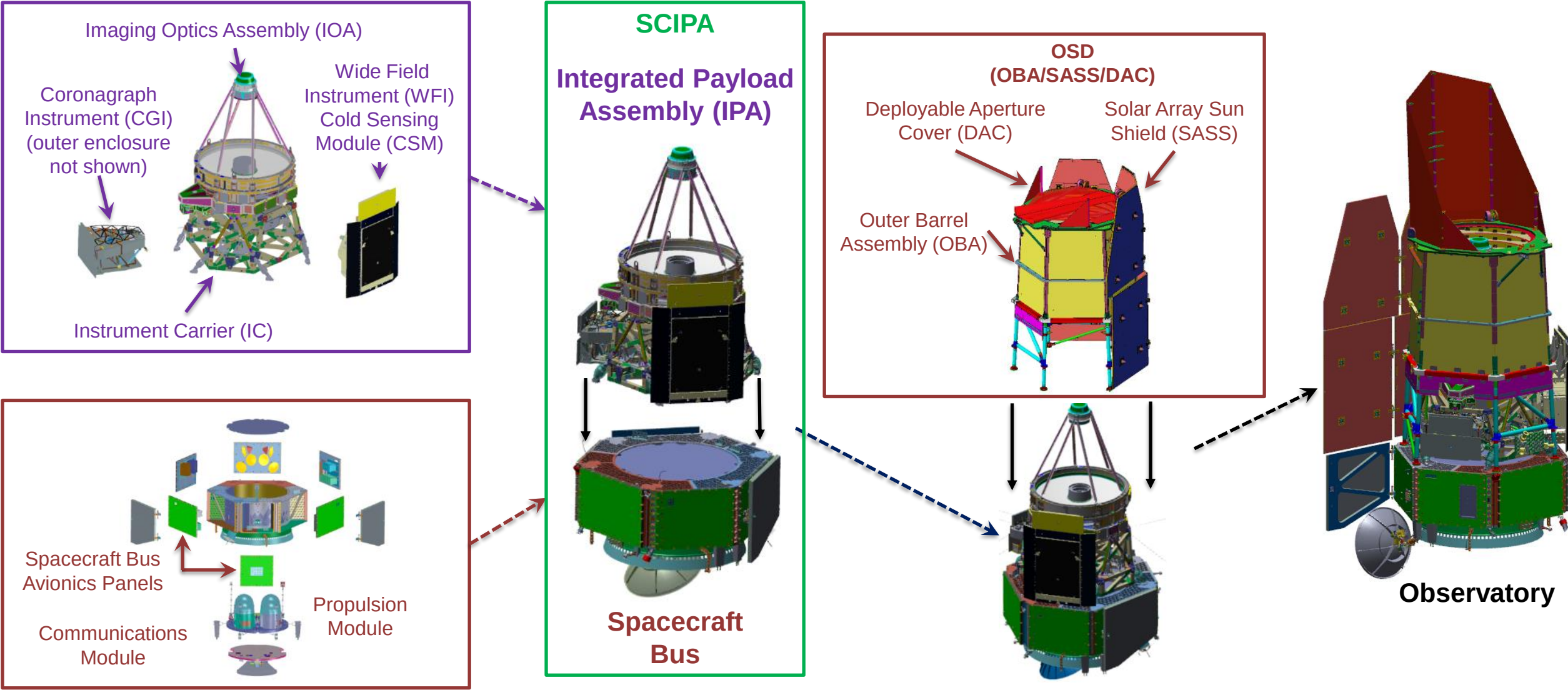
Status and Test

SPIE Mirror Tech Days
November 19, 2024
Greenbelt, MD

Matthew R. Bolcar
Roman Optical Systems Lead
Goddard Space Flight Center

Observatory Description

Observatory = **Spacecraft** + **Integrated Payload Assembly**

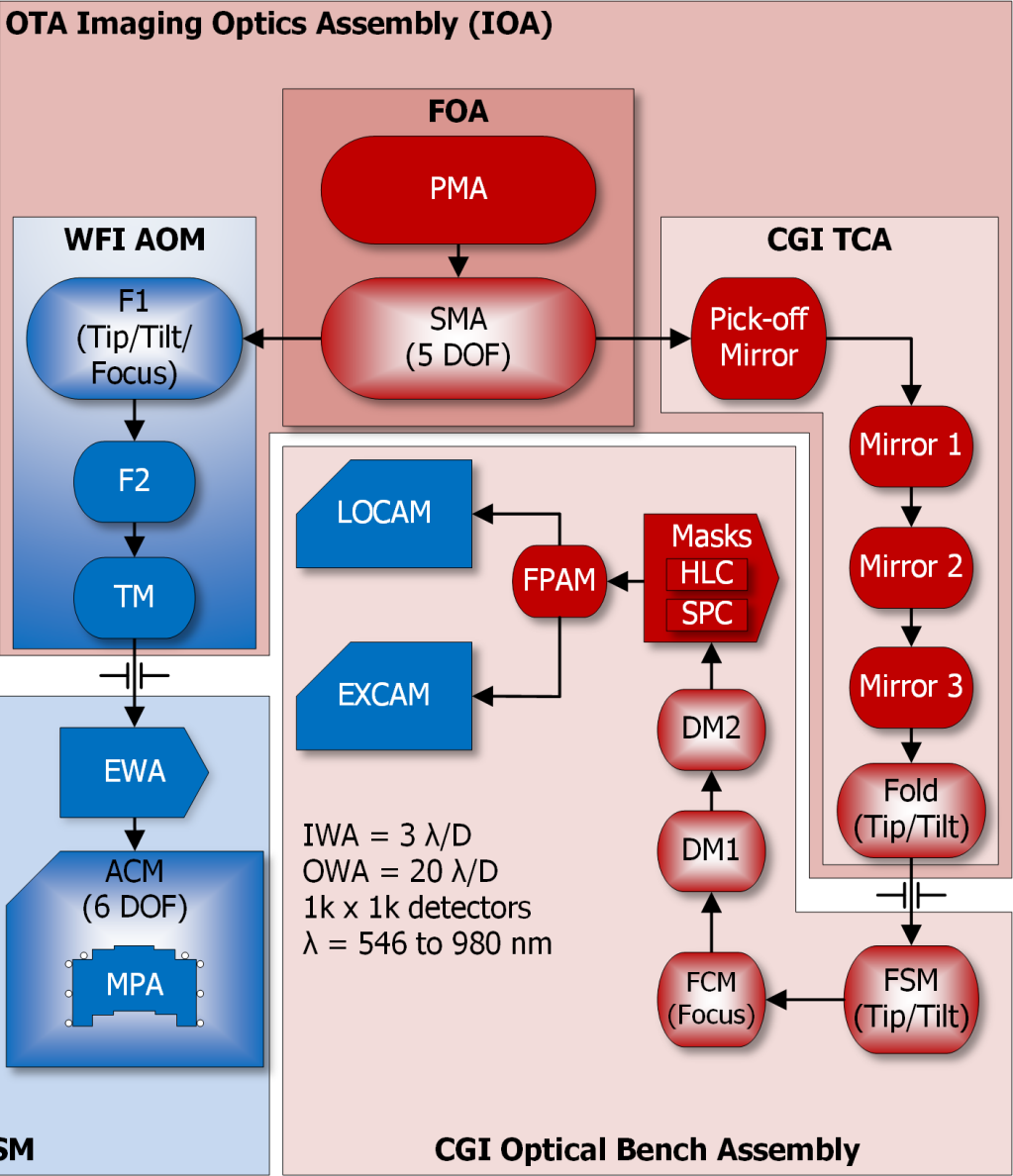


OPTICAL SYSTEM OVERVIEW

Optical System Block Diagram

LEGEND

- Optic
- Flight Compensator
- Focal Plane
- Mechanism
- Optical Path
- Optical Pupil



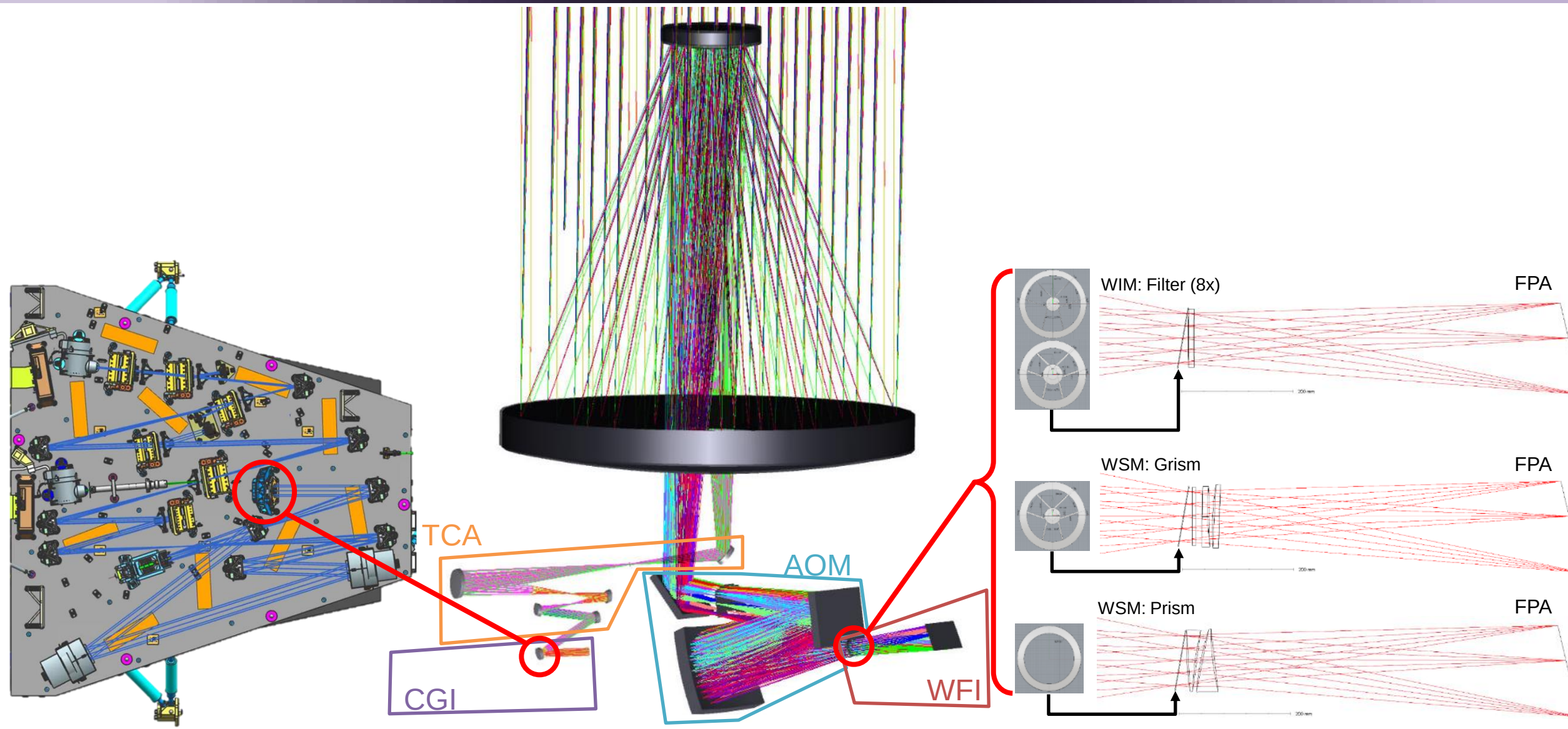
AOM = Aft Optics Module
ACM = Alignment Compensation Mechanism
CGI = Coronagraph Instrument
CSM = Cold Sensing Module
DM = Deformable Mirror
DOF = Degree of Freedom
EWA = Element Wheel Assembly
EXCAM = Exoplanet Camera
FOA = Forward Optics Assembly
FCM = Focus Control Mechanism
F1/F2 = Fold Mirror 1/2
FOA = Forward Optics Assembly
FPAM = Focal Plane Mask Precision Alignment Mechanism
FSM = Fast Steering Mirror
HLC = Hybrid Lyot Coronagraph
IOA = Imaging Optics Assembly
IWA = Inner Working Angle

LOCAM = Low Order Wavefront Sensing Camera
MPA = Mosaic Plate Assembly
OTA = Optical Telescope Assembly
OWA = Outer Working Angle
PMA = Primary Mirror Assembly
RCS = Relative Calibration System
SMA = Secondary Mirror Assembly
SPC = Shaped Pupil Coronagraph
TCA = Tertiary Collimator Assembly
TM = Tertiary Mirror
WFI = Wide Field Instrument

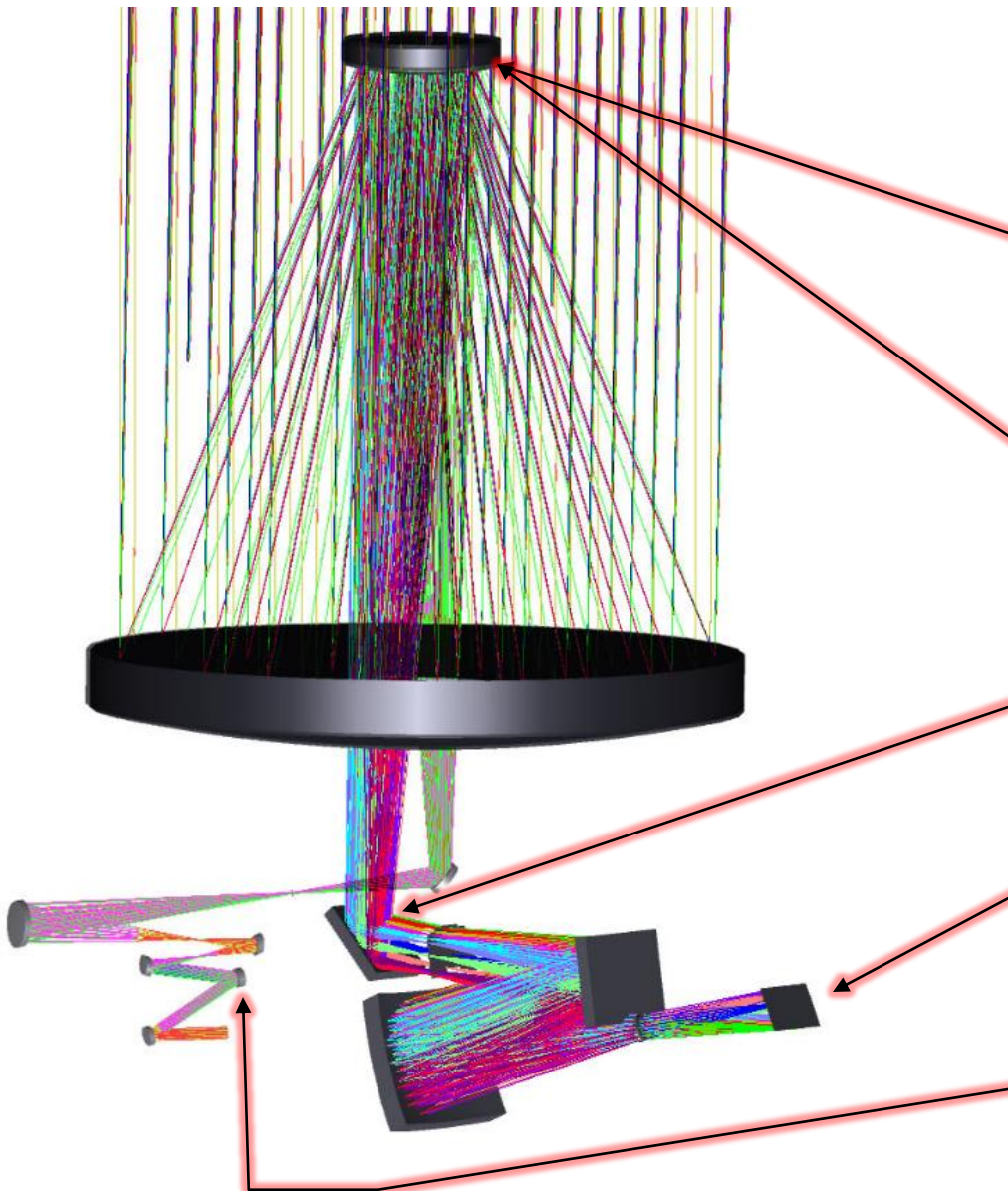
8 Filters
1 Grism
1 Prism
1 Cold Dark
18 H4RG detectors
10 μm pixel size
288 Megapixels
 $\lambda = 0.48 \text{ to } 2.3 \mu\text{m}$
0.28 deg^2 active area
110 mas/pixel
f/7.9

WFI CSM

Optical Path



Optical Compensators



Compensator	Degree of Freedom
SM Focus Drives (FD)*	Defocus
SM Alignment Drives (AD)*	Decenter (x)
	Decenter (y)
	Defocus
	Tip
	Tilt
AOM Fold Mirror 1 (FM1)	Defocus
	Tip
	Tilt
WFI Alignment Compensation Mechanism (ACM)†	Defocus
	Tip
	Tilt
TCA Tip/Tilt Fold (TTF)	Tip
	Tilt

*Heritage actuators from previous program

†Heritage JWST actuators

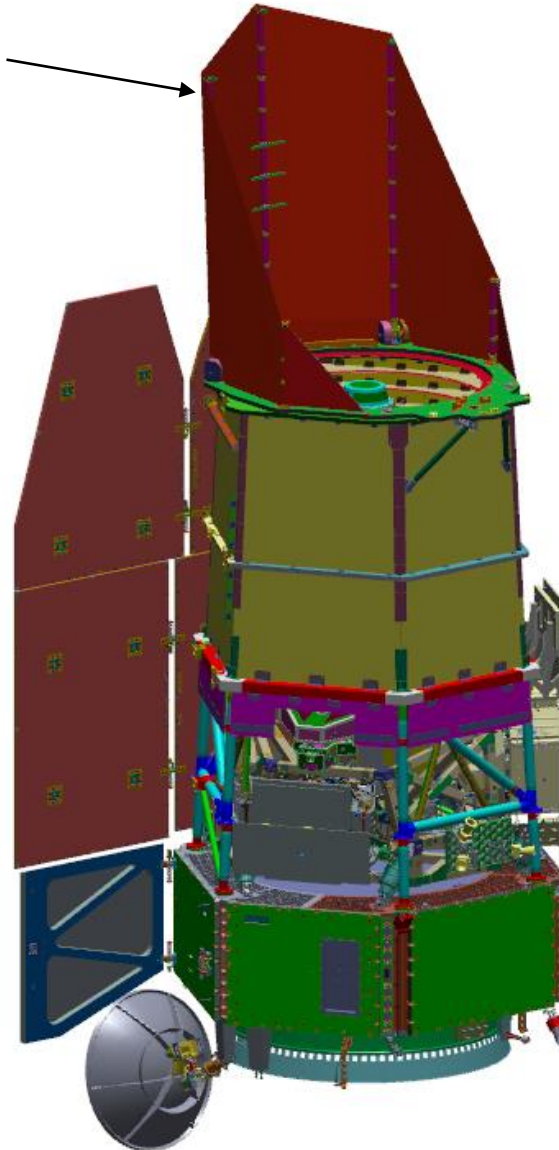
Compensate
Wavefront Error (WFE)
Errors Common to
Each Channel

Compensate Focus
& Pupil Shear in
WFI Channel

Compensate Pupil
Shear in CGI
Channel

Stray Light Controls

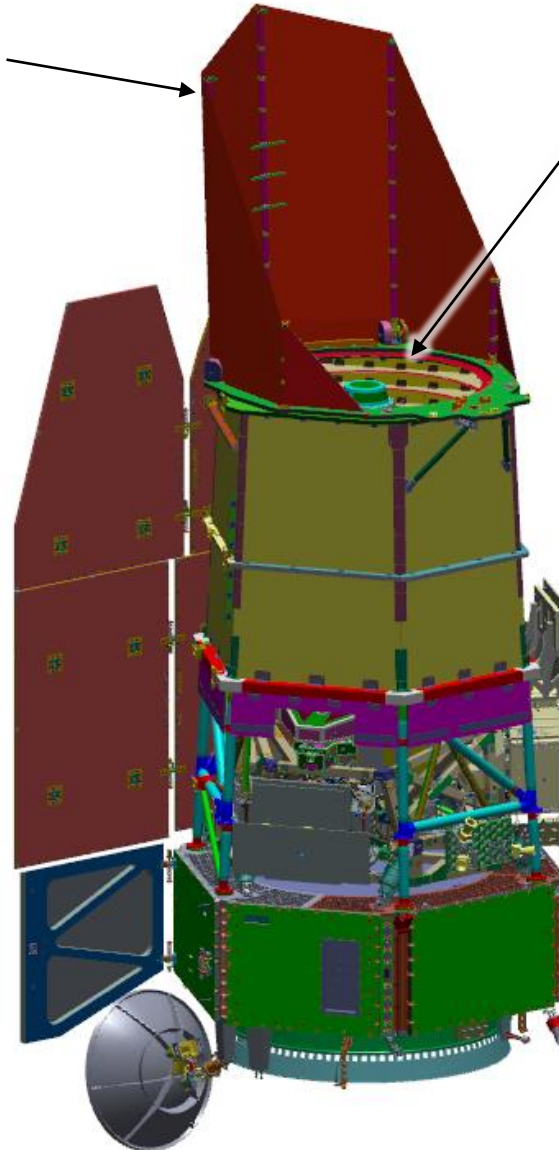
Deployable Aperture Cover
keeps direct sun from entering
the Outer Barrel Assembly (OBA)



Stray Light Controls

Deployable Aperture Cover
keeps direct sun from entering
the Outer Barrel Assembly (OBA)

OBA Baffle Vanes limit view of
OBA walls from sky & PM.



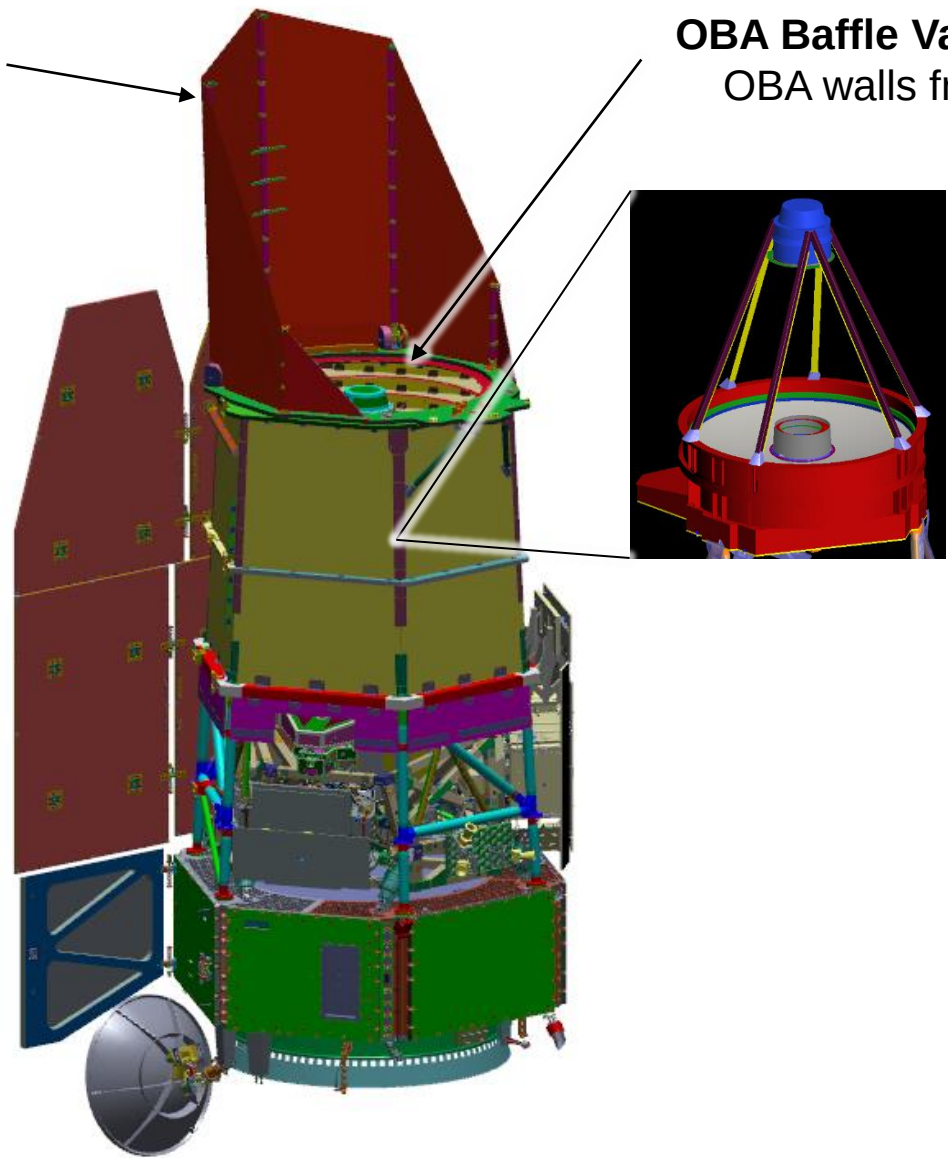
Stray Light Controls

Deployable Aperture Cover
keeps direct sun from entering
the Outer Barrel Assembly (OBA)

OBA Baffle Vanes limit view of
OBA walls from sky & PM.

Scrapers on SM and support
tubes limit reflections from
blankets

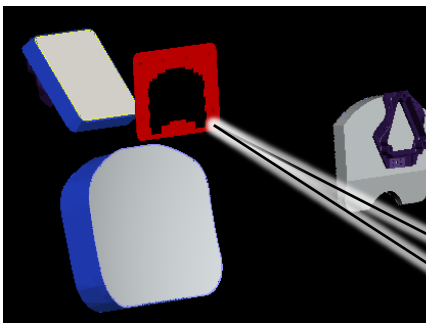
PM Baffle prevents direct
view of FM1 from sky



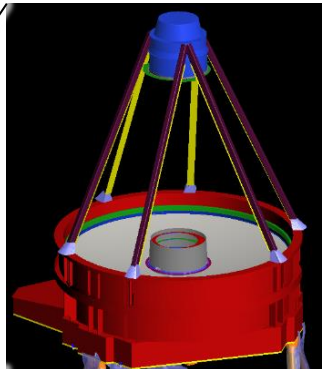
Stray Light Controls

Deployable Aperture Cover
keeps direct sun from entering
the Outer Barrel Assembly (OBA)

**Entrance aperture
plates** limit out-of-field
light in each instrument
(WFI shown)

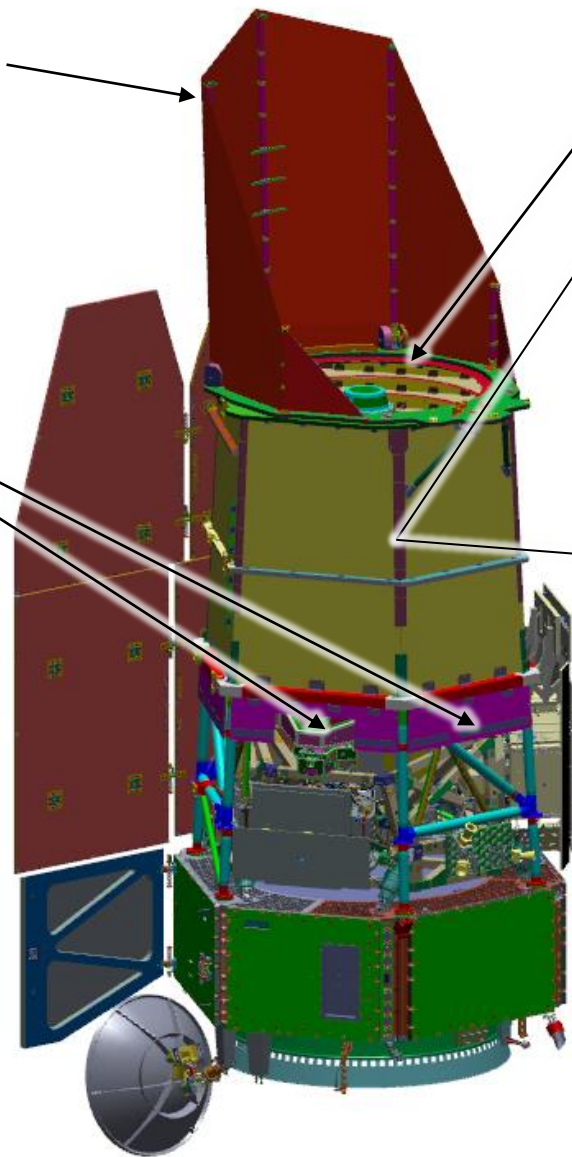


OBA Baffle Vanes limit view of
OBA walls from sky & PM.



Scrapers on SM and support
tubes limit reflections from
blankets

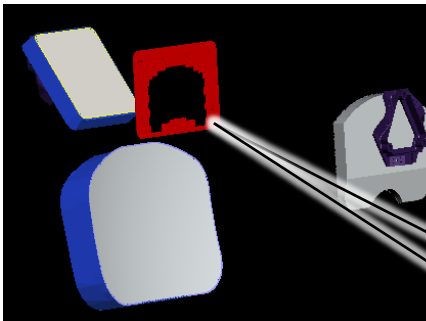
PM Baffle prevents direct
view of FM1 from sky



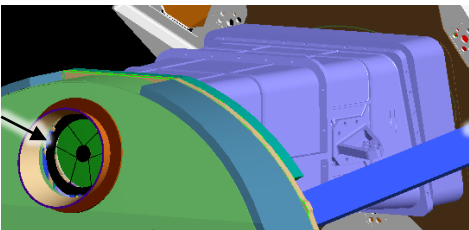
Stray Light Controls

Deployable Aperture Cover
keeps direct sun from entering
the Outer Barrel Assembly (OBA)

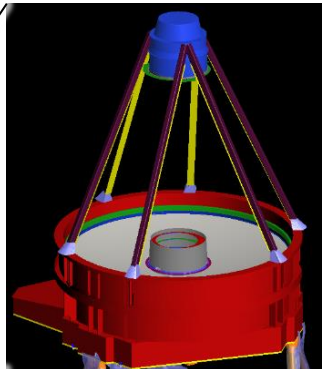
**Entrance aperture
plates** limit out-of-field
light in each instrument
(WFI shown)



Stray light guards
seal gap between
instrument & IOA
(WFI shown)

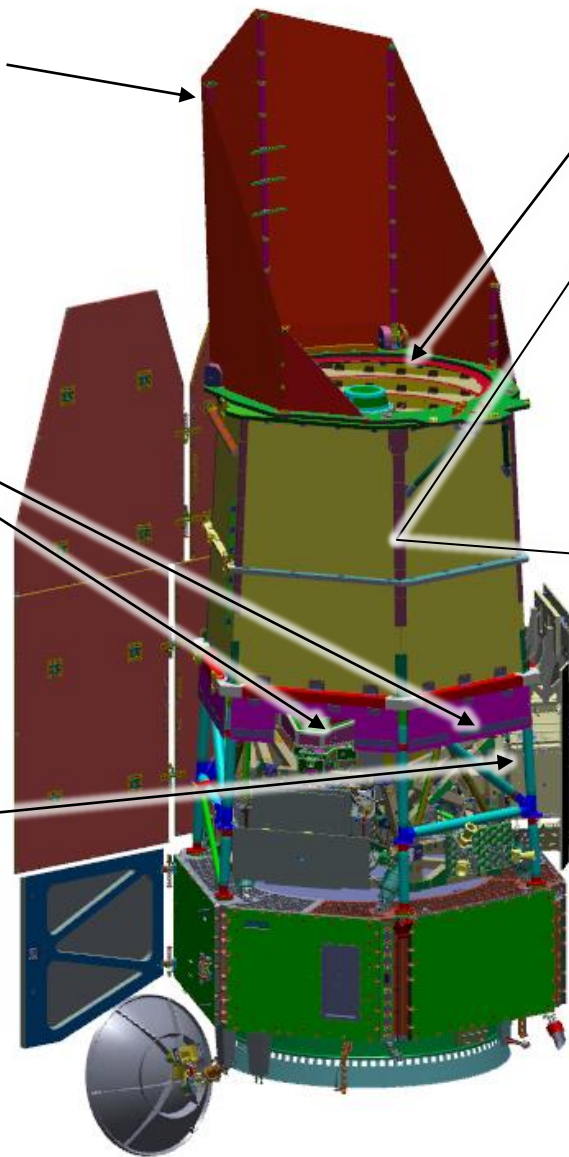


OBA Baffle Vanes limit view of
OBA walls from sky & PM.



Scrapers on SM and support
tubes limit reflections from
blankets

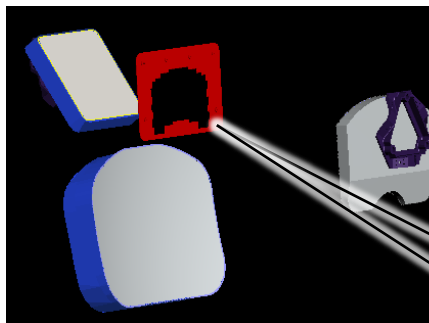
PM Baffle prevents direct
view of FM1 from sky



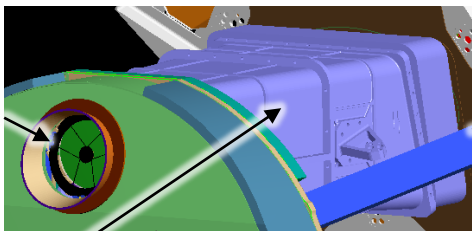
Stray Light Controls

Deployable Aperture Cover
keeps direct sun from entering
the Outer Barrel Assembly (OBA)

**Entrance aperture
plates** limit out-of-field
light in each instrument
(WFI shown)

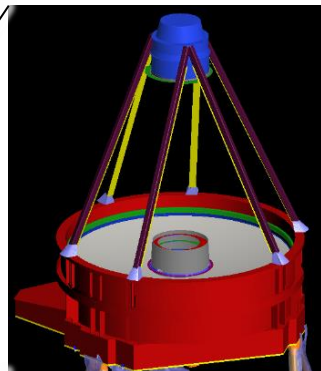


Stray light guards
seal gap between
instrument & IOA
(WFI shown)



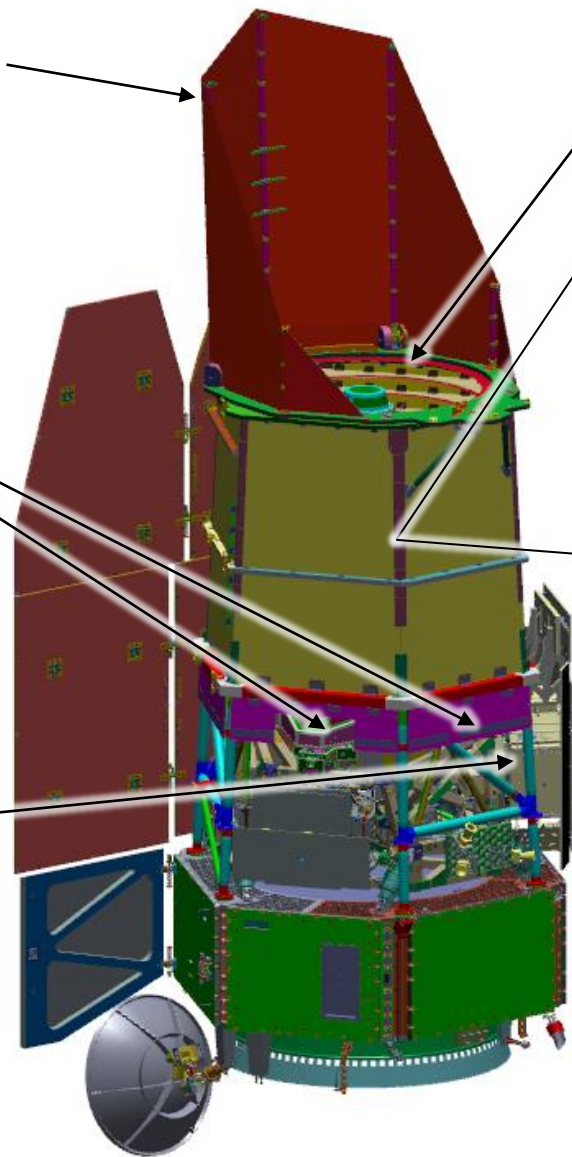
Cold Optics Baffle Assembly provides dark
cold environment for WFI FPA
CGI Blanket prevents direct view of sky
(not shown)

OBA Baffle Vanes limit view of
OBA walls from sky & PM.



Scrapers on SM and support
tubes limit reflections from
blankets

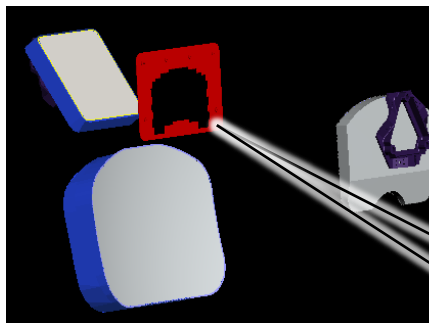
PM Baffle prevents direct
view of FM1 from sky



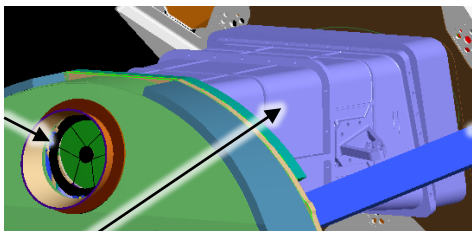
Stray Light Controls

Deployable Aperture Cover
keeps direct sun from entering
the Outer Barrel Assembly (OBA)

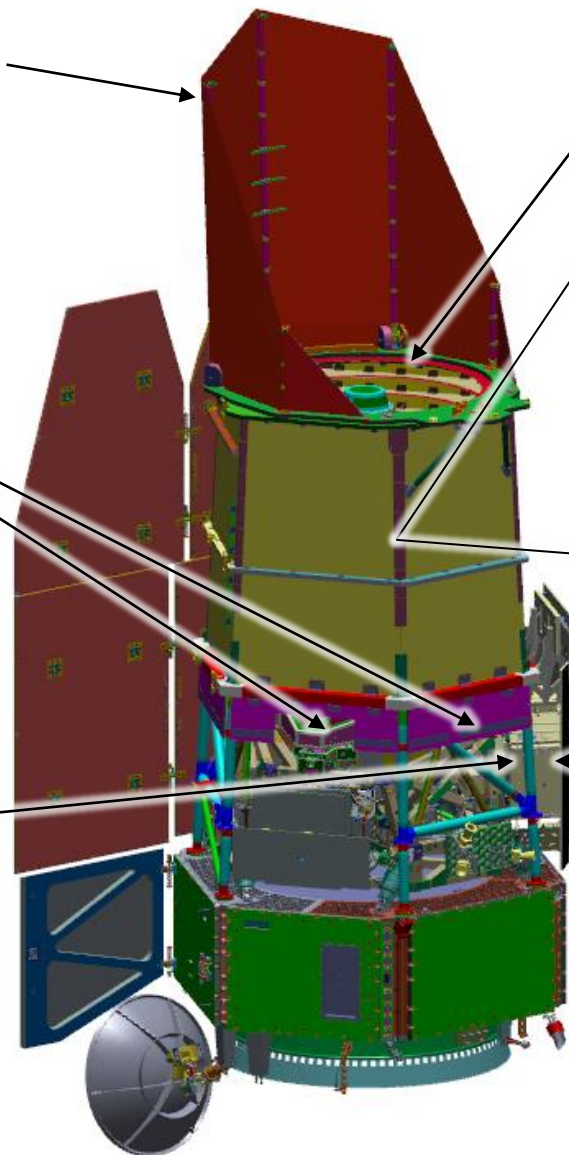
**Entrance aperture
plates** limit out-of-field
light in each instrument
(WFI shown)



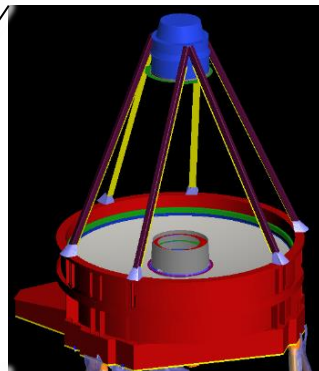
Stray light guards
seal gap between
instrument & IOA
(WFI shown)



Cold Optics Baffle Assembly provides dark
cold environment for WFI FPA
CGI Blanket prevents direct view of sky
(not shown)

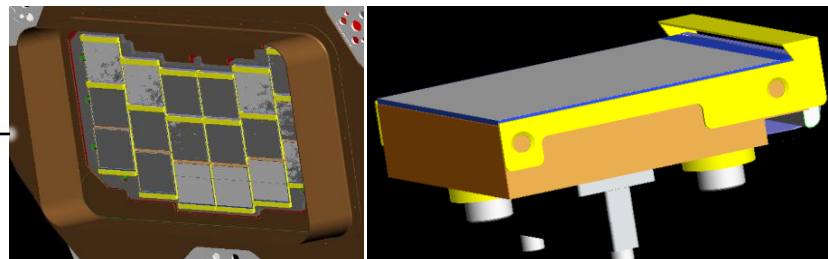


OBA Baffle Vanes limit view of
OBA walls from sky & PM.



Scrapers on SM and support
tubes limit reflections from
blankets

PM Baffle prevents direct
view of FM1 from sky



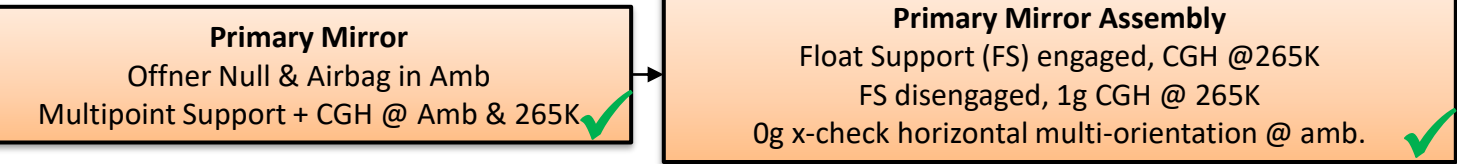
Labyrinth seal allows movement of the
FPA while closing stray light paths

SCA Wirebond Shield blocks out-of-field
light from shiny gold wires & bonds

TEST AND VERIFICATION SUMMARY

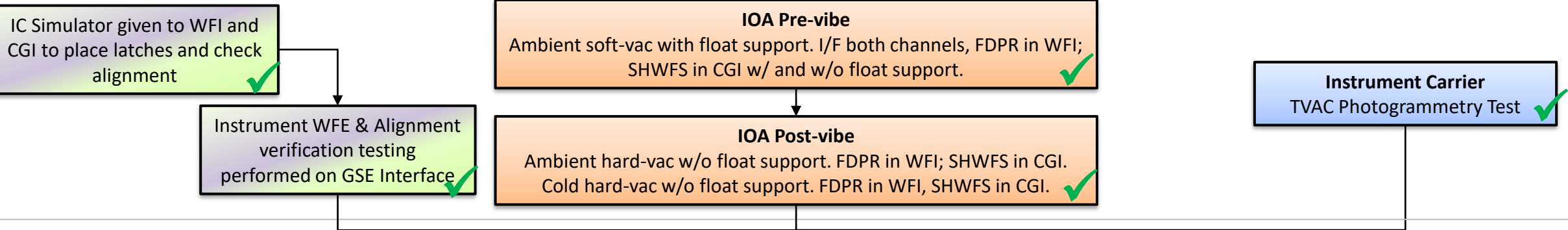
Optical Alignment & Verification Summary

Component Level

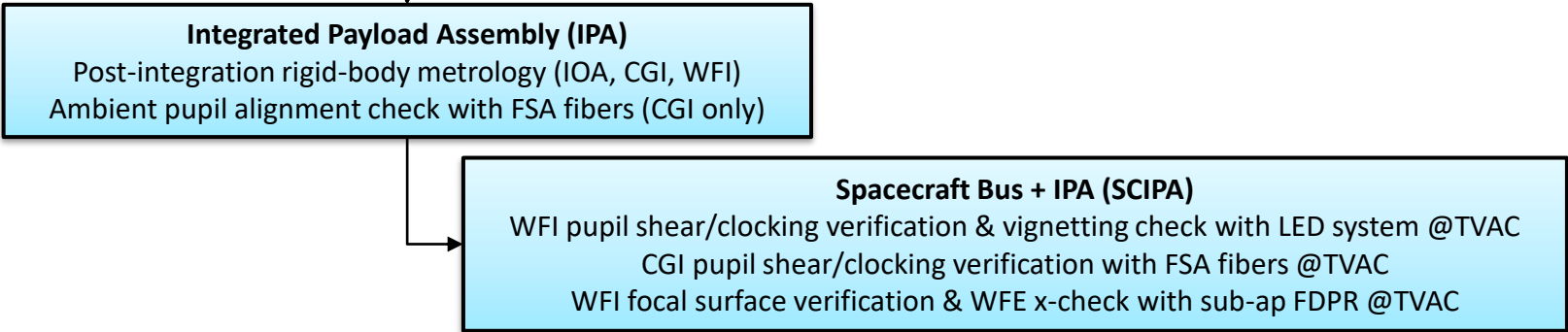


CGH = Computer Generated Hologram
FDPR = Focus Diverse Phase Retrieval
FSA = Forward Structure Assembly
I/F = Interferometry
SAVWI = System for Alignment, Vignetting, and Worming Inspection
SHWFS = Shack-Hartmann Wavefront Sensing
WFE = Wavefront Error

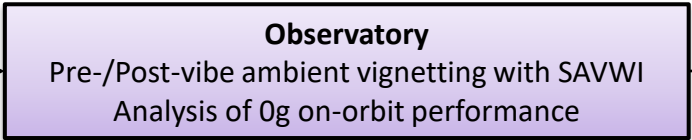
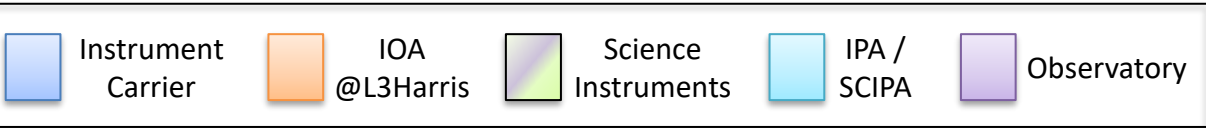
Element Level



Assembly Level



Observatory Level



Integration & Test with Alignment, Metrology, and Stray Light

- ★ Rigid-body Metrology
- ★ Pupil Alignment Check
- ★ SAVWI Test
- ★ Stray Light Inspection

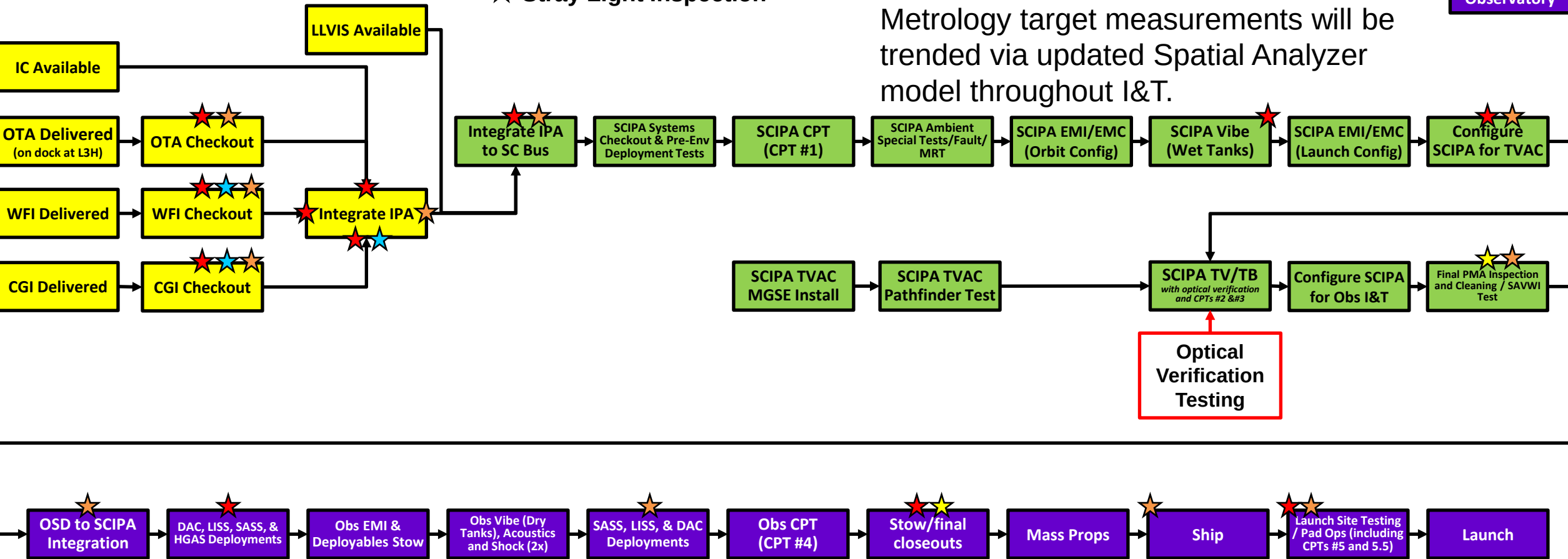
Stray Light model will be updated to reflect inspections.

Metrology target measurements will be trended via updated Spatial Analyzer model throughout I&T.

IPA

SC / IPA

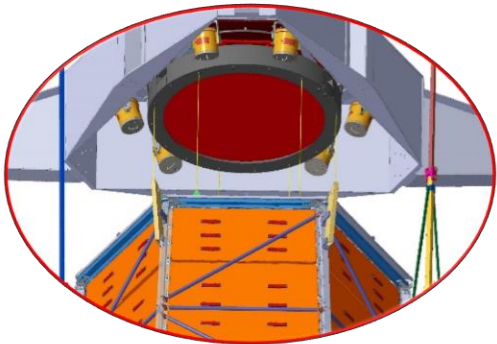
Observatory



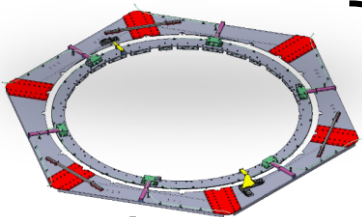
SCIPA TVAC TEST

SCIPA Test Configuration

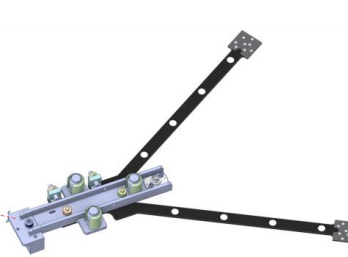
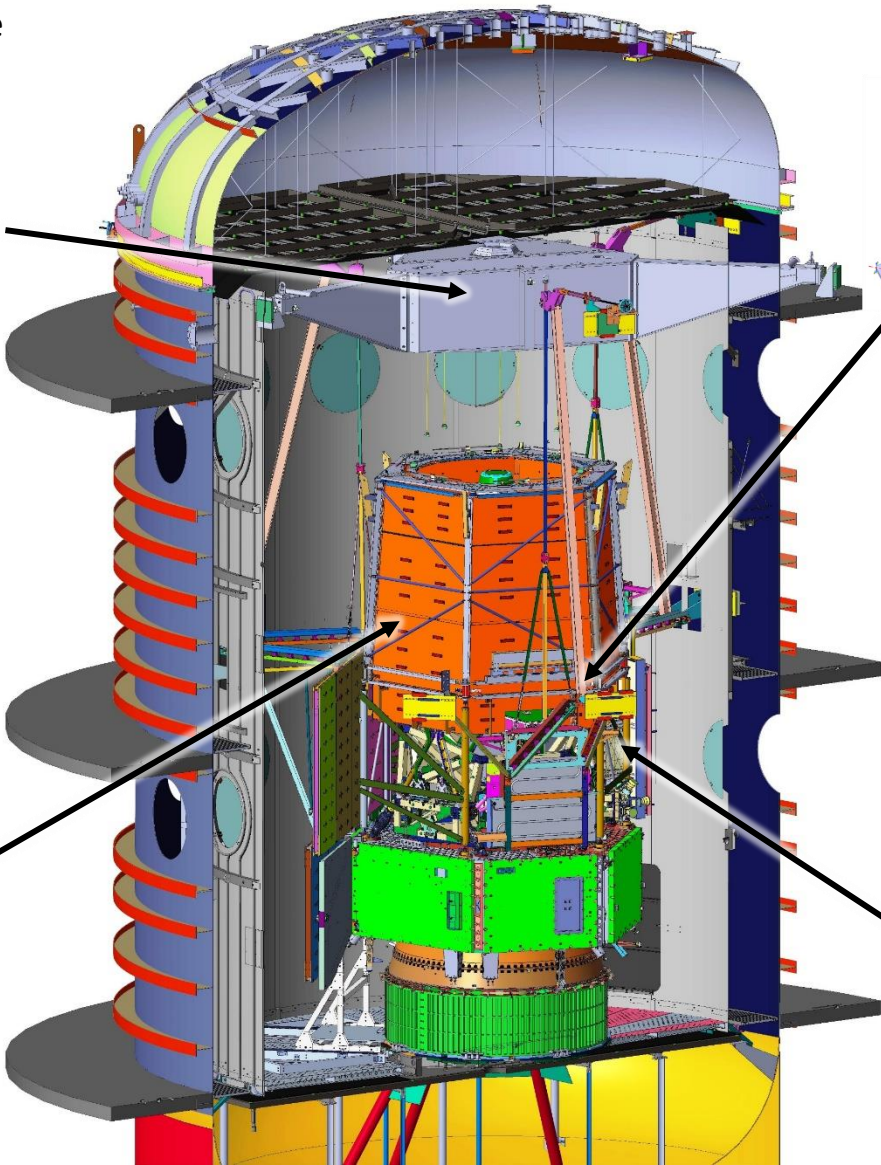
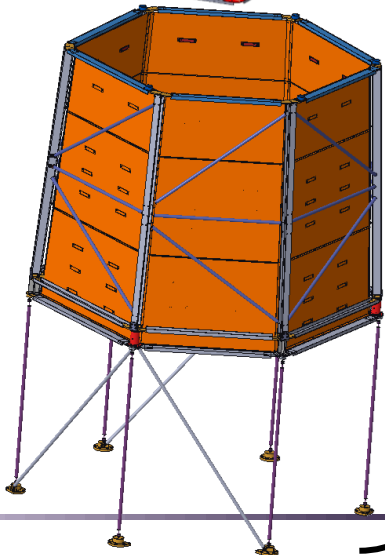
Upper Support Frame holds sub-aperture auto-collimating flat, photogrammetry cameras, and isolation system.



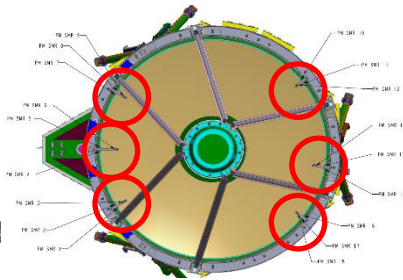
OBA-Sim top deck assembly supports LED System as well as photogrammetry targets



Outer Barrel Assembly Simulator (OBA-Sim) provides thermal environment and supports photogrammetry cameras for system alignment.



Non-flight fibers mounted around the perimeter of the primary mirror provide pupil sources for measuring CGI pupil alignment.



8 fibers mounted around the WFI focal plane array allow for double-pass testing of the system using focus-diverse phase retrieval.



Test Overview

Objective(s): Verify CGI-to-IOA pupil shear and clocking error

When are fibers used:

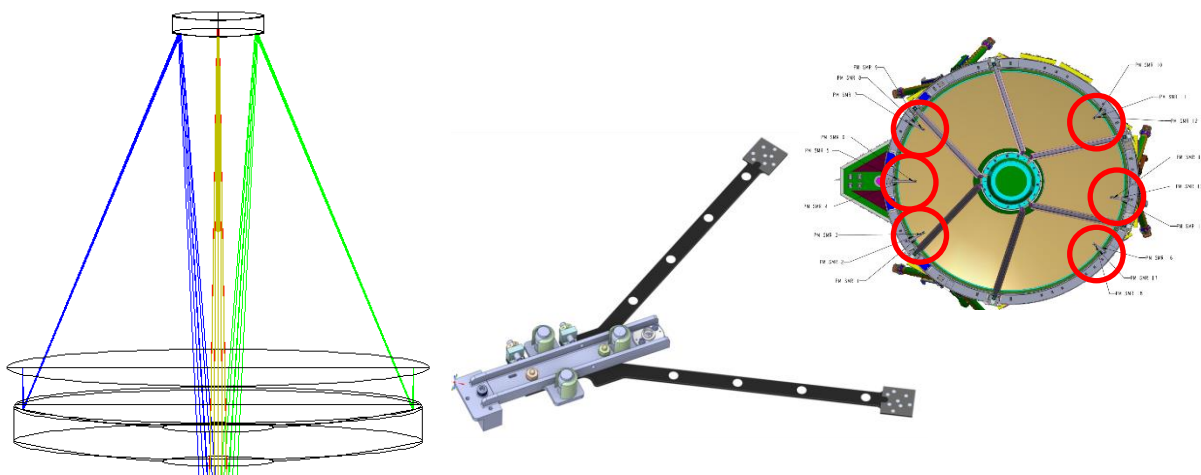
- IOA-level tests
- Post-CGI Integration (ambient)
- Post-SCIPA Vibe (ambient)
- SCIPA TVAC

Test Description

Description:

- Fiber sources on “diving boards” attach to OTA FSA, above the primary mirror
- Source external to chamber injects laser illumination into fibers
- Illumination in OTA entrance pupil is re-imaged in CGI exit pupil by pupil imaging lens
- Position of fiber-source images on the CGI ExCam gives relative alignment of the IOA exit pupil to the CGI instrument pupil

Test Configuration(s)



Test Status

- Hardware initially demonstrated during OTA thermal vacuum testing at L3Harris
- Extensions will be added to diving boards for SCIPA test to hold PG targets to serve as Payload Coordinate System (PCS) references
- Test will next be performed once the IOA is installed on the Instrument Carrier with CGI

Light Emitting Diode (LED) System

Test Overview

Objective(s):

- Verify WFI-to-IOA pupil shear and clocking error
- Verify no vignetting in WFI channel

When are LEDs Used :

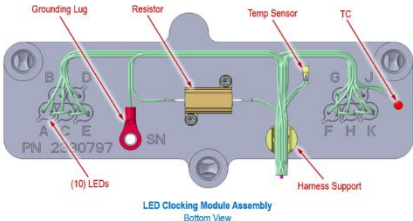
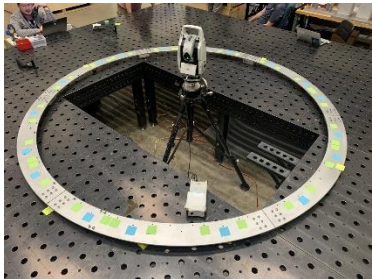
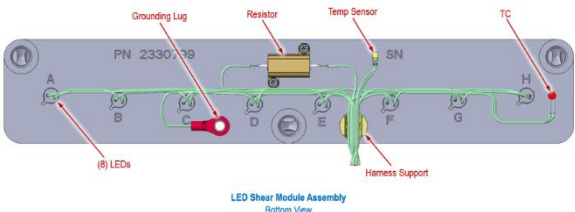
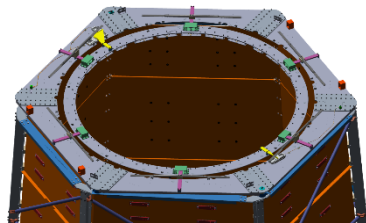
- Pathfinder TVAC
- SCIPA TVAC

Test Description

Description:

- 252 LEDs arranged around perimeter of PM, and clustered around secondary mirror support tubes
- Turn on each LED individually, measure resulting shadowgram at WFI focal plane for both F158 and F184 mask geometries
- Relate shadow edge positions to physical hardware positions in telescope or instrument pupils
- Independent image processing algorithms: traditional ray trace and machine learning

Test Configuration(s)



Test Status

- 12 test LEDs qualified at 205 K and output power verified
- Full LED ring has been constructed and functional test of all LEDs has been completed
- All LED hardware will be tested during SCIPA Pathfinder TVAC
 - LED operation optically verified in ambient conditions
 - LED current and voltage monitored during TVAC

Optical Large Aperture Flat System (OLAFS)



Test Overview

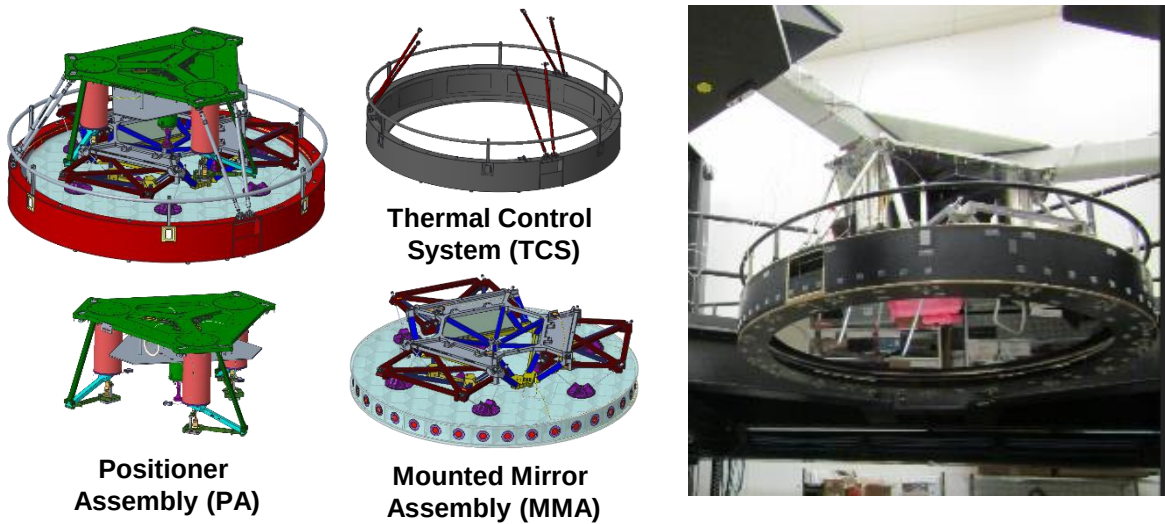
Objective(s):

- Verify WFI channel focal surface placement, tip/tilt
- Cross-check WFI channel wavefront error (WFE)

When is GSE Used :

- Pathfinder TVAC
- SCIPA TVAC

Test Configuration(s)



Test Description

Description:

- Double-pass focus-diverse phase retrieval (FDPR) uses fiber sources incorporated in the WFI mosaic plate assembly
- OLAFS 1.8-m mirror at top of chamber reflects beam back into the WFI channel
- Tip/tilt of OLAFS used to steer beam across the field-of-view
- WFI alignment compensation mechanism (ACM) moves through focus to generate focus diversity

Test Status

- OLAFS delivered in May 2024
 - Mirror performance was verified in ambient conditions via skip test and stitching-collimator test
- OLAFS has been integrated into the upper support frame and functional and full range of motions tests have been completed
- Function will be re-checked TVAC conditions as part of SCIPA Pathfinder test

Test Overview

Objective(s):

- Provide alignment knowledge of optical test equipment during SCIPA TVAC

When is GSE Used :

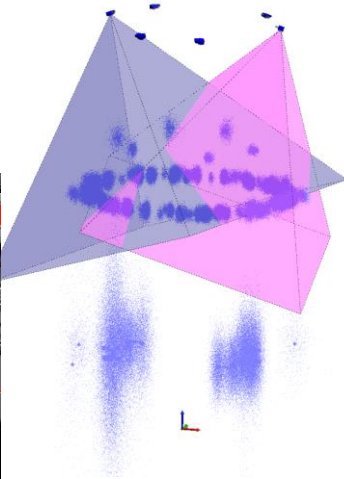
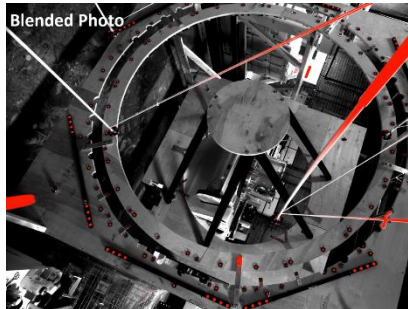
- Pathfinder TVAC
- SCIPA TVAC

Test Description

Description:

- 6x stationary PG cameras located in the upper support frame around OLAFS continuously monitor the alignment of
 - FSA diving board with extensions (PCS reference)
 - LED ring
 - Targets attached to OLAFS thermal ring
- PG measurements ensure the forward models used in analysis are accurate

Test Configuration(s)



Test Status

- PG cameras, canisters, purge system, and LED flash system have been demonstrated and calibrated in testbed (photos at left)
- Testbed and calibration data being used to develop analysis pipeline and validate measurement uncertainties
- PG system will be demonstrated during SCIPA Pathfinder TVAC

Test Overview

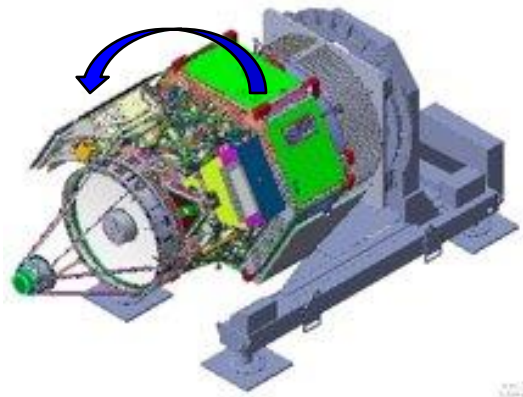
Objective(s):

- Inspect mirror surface(s) for coating worming degradation
- Inspect optical path for vignetting
- Coarse check of pupil alignment

When is GSE Used :

- Post-SCIPA TVAC baseline (ambient measurement)
- Post-Observatory environmental testing (ambient measurement)

Test Configuration(s)



Test Description

Description:

- Digital camera with 300-800 mm zoom lens and LED illumination system, metrologized and positioned in front of OBA aperture
- SCIPA / Observatory oriented with optical axis parallel to ground
- Adjust focus to individual optical surfaces, as far back as WFI aperture and CGI fast steering mirror
- Image known worming locations to look for changes; look for new worming
- Look for obstructions in ray path (vignetting)
- Check pupil alignment by measuring WFI pupil mask references

GSE Status

- Camera system in-hand; Performance demonstration planned on the Fifth-scale Testbed (FSTB)
- Mounting / motion control hardware will be specified and procured based on demonstration lessons learned

- **Integration and test of the Roman Space Telescope is well underway!**
 - All Elements have been delivered to GSFC and integration of the Payload has begun
- **A comprehensive optical verification plan has been established**
 - All Elements have been fully optically verified at operational temperature prior to delivery to payload integration
 - Final system alignment is verified at GSFC at operational temperature with additional cross-checks to ensure system integrity through I&T
 - Test verification budgets and test plans are in development
- **The Roman Space Telescope is on track for an October 2026 launch!**