ROMAN
SPACE TELESCOPE

NASA

Roman virtual lecture series: History of the Roman observatory design, and current build status

Dave Content

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• NASA GODDARD SPACE FLIGHT CENTER • JET PROPULSION LABORATORY •
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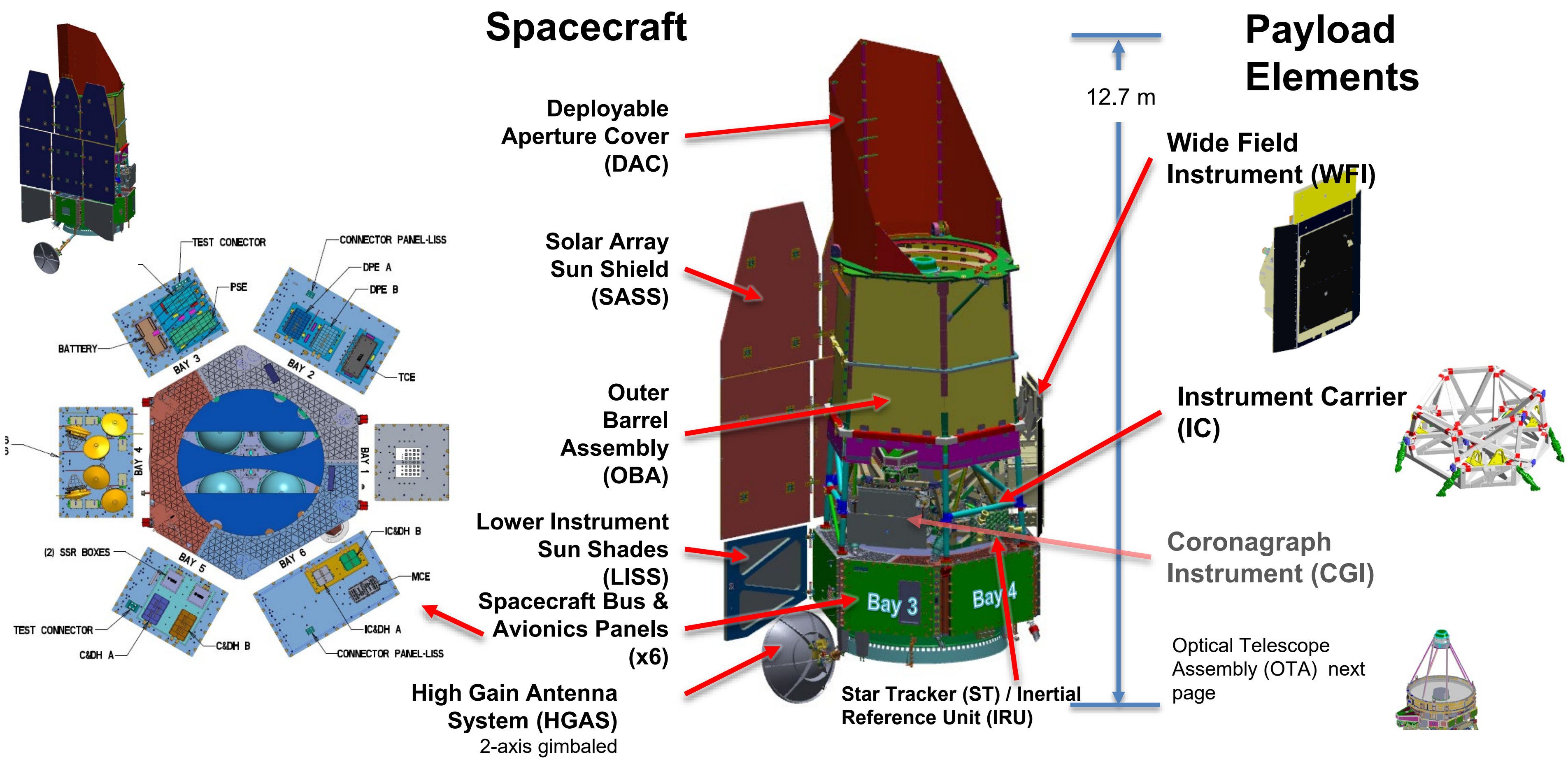
One-Page Mission Background

- **WFIRST (widefield infrared survey telescope, prior mission name) was creation of 2010 NWNH Decadal**
  - Based on JDEM "Omega", Microlensing Planet Finder, and NIR Surveyor mission concepts
    - All were three mirror anastigmat near IR staring concepts
    - JDEM Omega was hardware starting point, but needed to be slightly modified to accommodate continuous viewing periods of the galactic bulge for microlensing
  - Multiple different surveys rolled into one mission
  - Imaging, imaging spectroscopy, and precision photometry are all required among the surveys
  - Cooler than HST optics are required for 2.0um red limit
    - HST is background limited near room temperature and 1.7um red limit
- **Mission concepts through 2011 were 1.5m on axis or 1.3m off-axis apertures**
- **2.4m aperture (NRO transferred to NASA, we were directed to us, in 2012)**
  - Larger primary mirror has 3x area and 0.5x PSF size, ~20x discovery potential
  - Realized best design has undersampled PSF with survey strategy to recover full sampling, best compromise of sampling vs wide area coverage
- **Concept evolved significantly with our understanding of the existing optics**
  - Started with "use as is"; evolved over time towards current concept
  - Overall design has been very stable after early evolution described here
- **Renamed in 2020 after Nancy Grace Roman; progressing toward launch readiness in Oct2026**

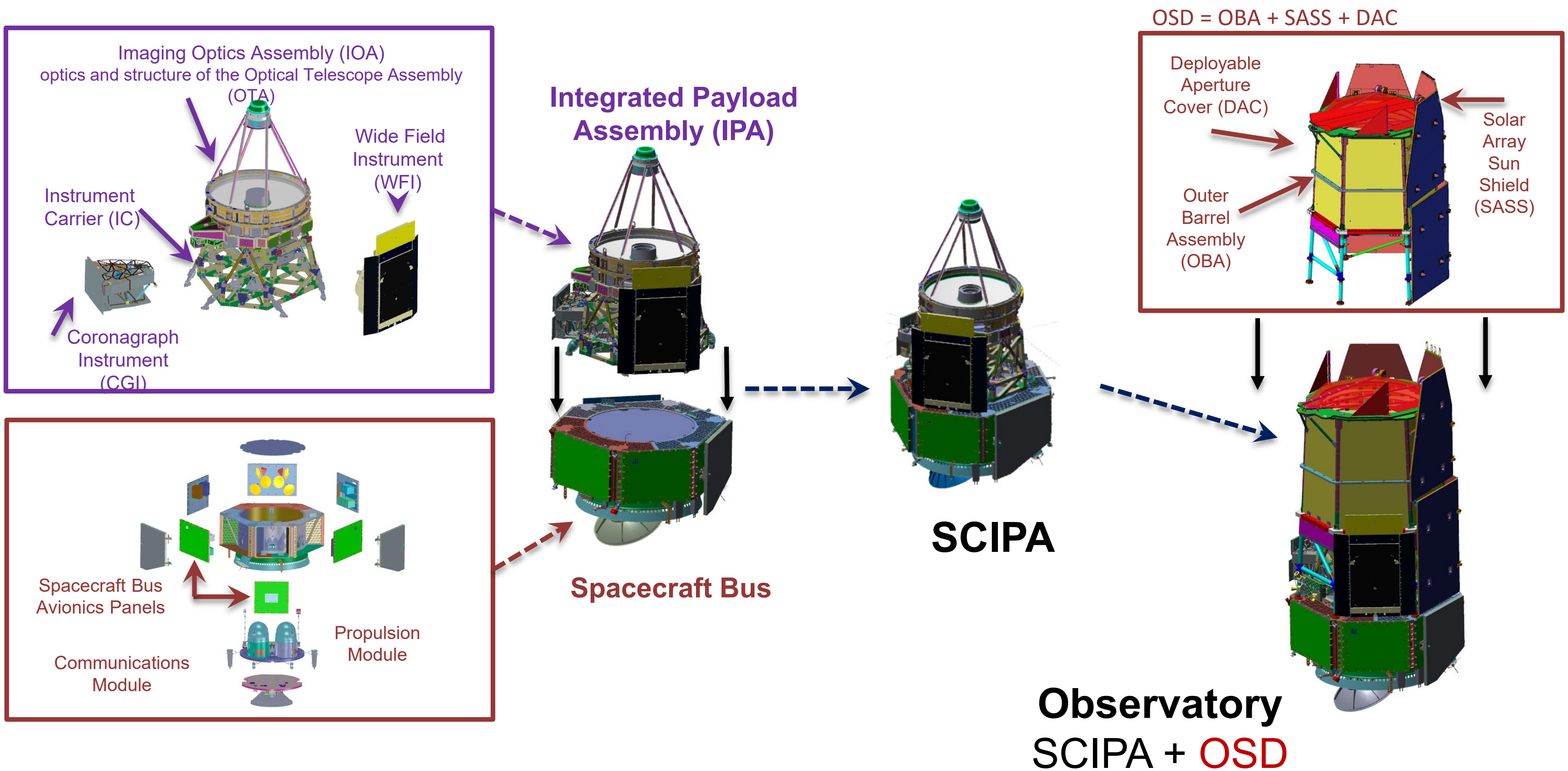
Roman Observatory Hardware



Roman Observatory

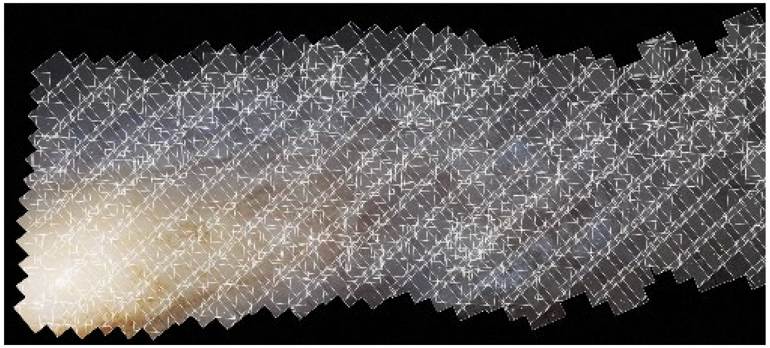
Expanded View with Integration Flow

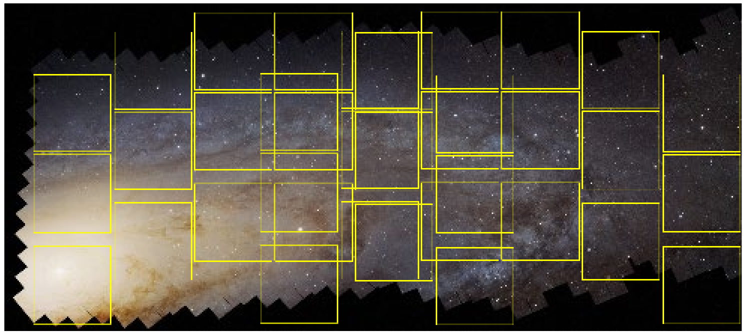
SCIPA = Spacecraft Bus + Integrated Payload Assembly



Roman Science (1 of 3)
Roman as a Precise Survey Facility

- **The power of Roman is not *just* the large field of view:**
  - Very efficient observations: >1000x HST survey speed
    - Rapid slew & settle
    - No Earth occultations
    - No South Atlantic Anomaly
  - Well understood and stable PSF
    - Stable thermal environment (L2 orbit, thermal control of all parts of the optical system)
    - Rigid optical structure with vibration isolation from the spacecraft
    - Stable attitude control
  - Excellent flux calibration
    - onboard Relative Calibration System

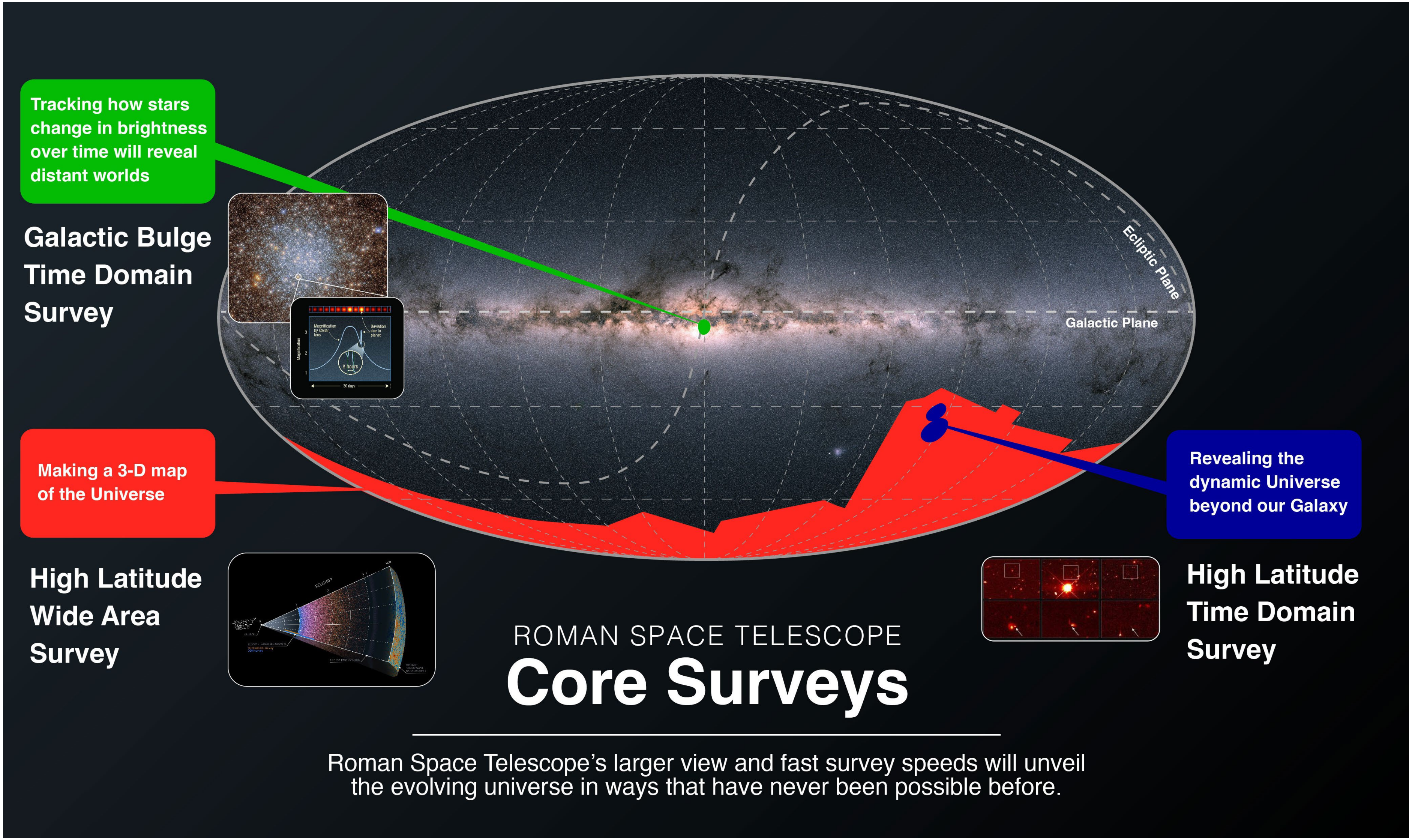




Roman Science (2 of 3)
Roman Observations

- **Three Core Community Surveys address the 2010 Decadal Survey science goals while providing broad scientific power**
  - **High Latitude Wide Area Survey**
    - Wide area multiband survey with slitless spectroscopy
    - Enables weak lensing and galaxy redshift cosmology mission objectives
  - **High Latitude Time Domain Survey**
    - Tiered, multiband time domain observations of 10s deg^2 at high latitudes
    - Enables Type Ia supernova cosmology mission objectives
  - **Galactic Time Domain Survey**
    - ~<15 min cadence observations over few deg^2 towards galactic bulge
    - Enables exoplanet microlensing mission objectives
- **Minimum 25% time (>1.25 yr) allocated to General Astrophysics Surveys**
- **90 days for Coronagraph technology demonstration within first 18 months of mission**

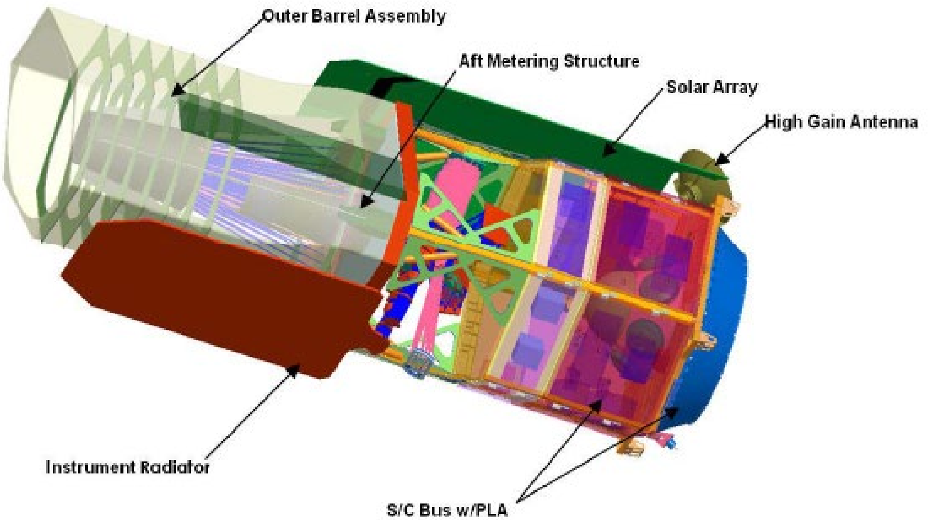
Roman Science (3 of 3)
Core surveys mapped to the sky

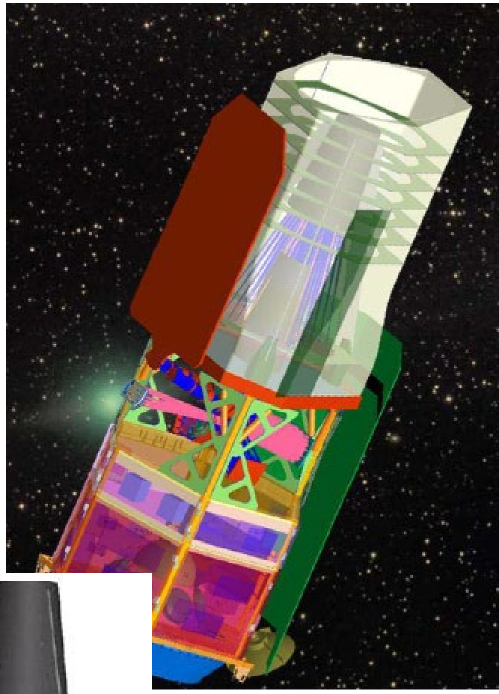


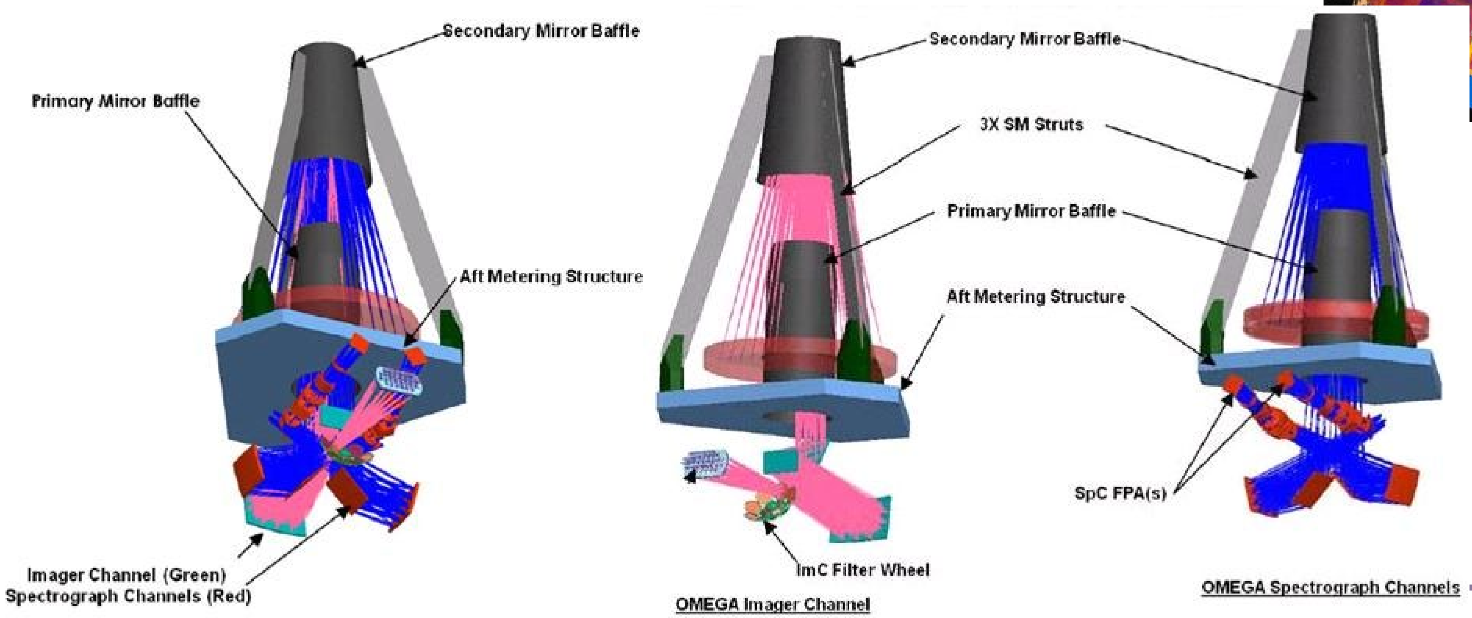
All-sky projection in Galactic coordinates, with Roman core Survey areas color-coded

Omega – decadal winning point design

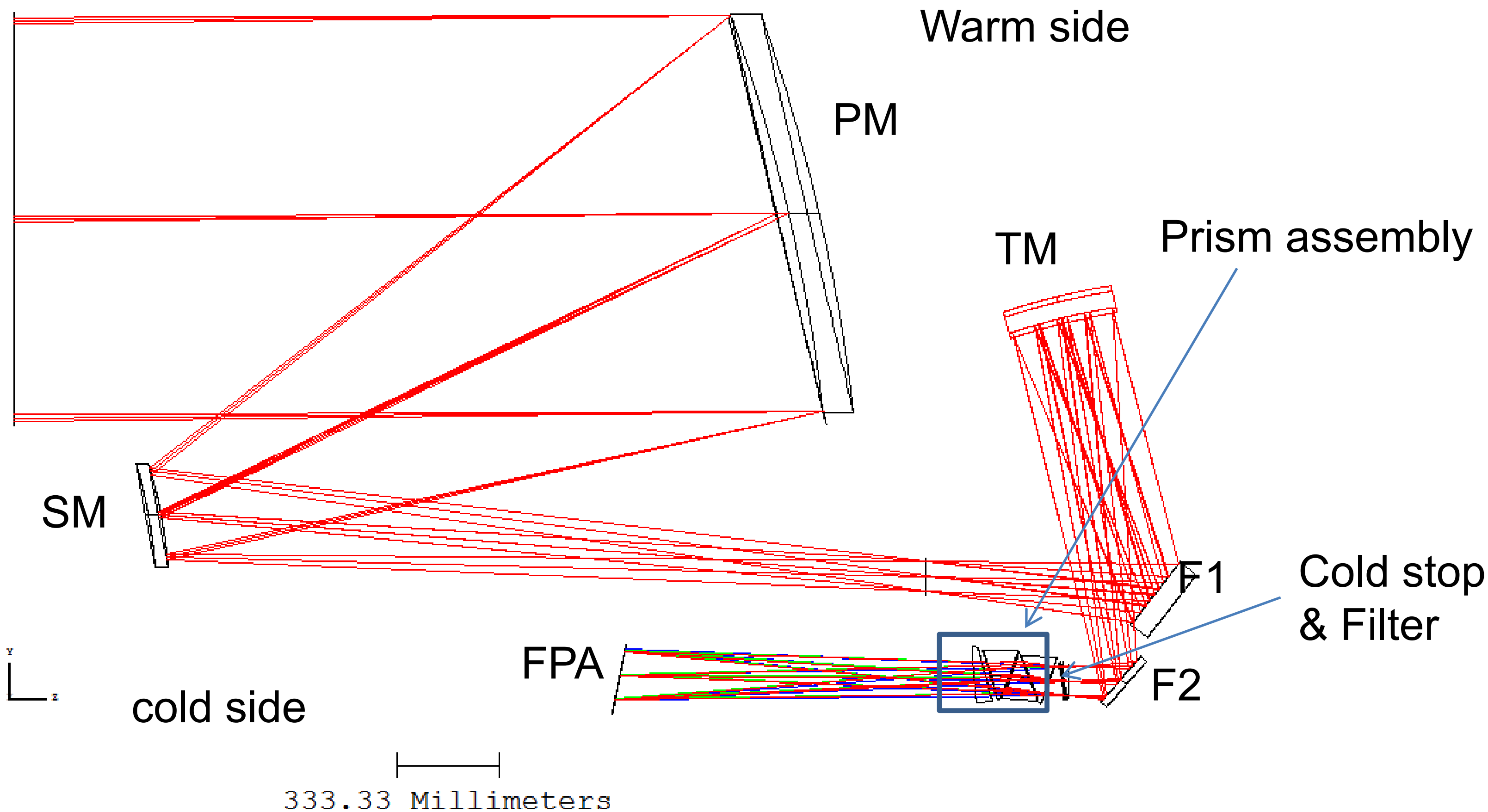
Figure 5 – Observatory Configuration







DRM1 (2012)– 1.3m off axis telescope; single larger field of view, focal prism for spectroscopy



Early thinking on 2.4m optical & thermal design

- **Soon after transfer of optics to NASA in 2012, we learned:**
  - Based on PM, SM prescription, several GSFC optical designers realized original design would not provide a sufficiently wide field. Design change and adjustment of optics would be needed to optimize the science
  - Mirrors inspected; Protected Ag coatings had aged, needed to recoat
  - Ion figuring uses same hardware configuration as recoating, and is quick
  - Therefore conic constant change is low incremental cost
  - SM would be relatively quick and inexpensive to regrind & polish
    - Constraint to keep intervertex spacing close to original value so redesign of secondary metering struts and other supporting structures would not be necessary
    - These are very different design constraints from a “clean sheet” new design
- **Worked to determine how cold the existing hardware could operate**
  - PM, SM at ~265-270K, new back end for WFI ~220K, consistent with 2.0um red limit
- **The utility of a coronagraph is a very strong function of telescope diameter; thus the move from 1.5m to 2.4m generated a consideration and finally baselining of the coronagraph (built by JPL, with contributions from university and foreign partners)**
  - CGI specifics were consistent with both “Hybrid Lyot” and “Shaped Pupil” types of coronagraph

“Phase B” == Flight design

- **Optics**
  - Very undesirable/difficult to test optical interface w/ tertiary (optically powered) mirror (TM) in WFI. Placed TM and fold mirrors in telescope
  - Final optical prescription is f/8 “vanilla” Three Mirror Anastigmat; coaxial conic PM & SM, near axis conic TM. CGI is fed using a steerable collimated beam picked off from a separate field of view
  - Curved field layout (“smile”) preserves axisymmetric TMA form with workable CGI and large field for WFI, and no vignetting, and a pupil placed (just) far enough from the telescope for WFI/OTA clearance
  - Spectroscopy elements: Grism (higher resolving power, ~1-2um) and prism (lower resolving power, more sensitive) use novel optical designs to achieve large field of view and survive and perform at 170K operating temperature
    - Wide field spectroscopy optics at 170K were challenging to design/build/test, at least 5 year effort
  - Filters are spherical surfaces, designed for loosest alignment tolerances in a converging beam
- **Thermal**
  - Dedicated “external” radiator for cooling WFI focal plane was improved to an integrated multistage radiator by Ball once they won the contract for the widefield instrument optomechanical component, and by tweaking the design to push the focal plane radially outward
  - A lot of work to enhance thermal stability, active control of IC, OBA, OTA
- **Pointing – WFI focal plane is the fine guider**
  - 4k x 4k HgCdTe sensors include guide window capability
  - Mechanical isolation at S/C interface to payload (“launch load & vibration isolation system”, LLVIS, and local isolation at S/C reaction wheels)
  - Procured high torque reaction wheels, enables faster slews

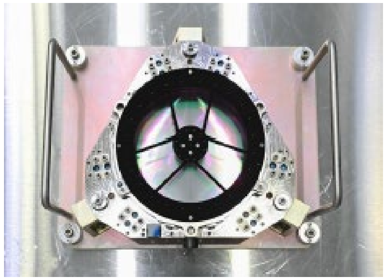
Design drivers

- **Cost has been a driver. We get all of the attention one might expect for the first flagship after JWST.**
  - Funding has been very steady. When government has been funded, we have been fully funded. This has helped tremendously with keeping up momentum.
- **Stability – thermal and optical stability drive key science survey systematics. We anticipate nm level optical wavefront stability over our short observations, which meets even the most stringent science need.**
  - Novel tests at telescope level to assist stability model correlation
  - Rigorous integrated modeling with external audit team
- **Reuse of existing hardware – the existing OTA components rippled through the whole design, setting the observatory scale and driving many aspects of the design**
- **Data flow – the raw data rate from WFI is ~2Gb/sec and must be handled and averaged down to daily download limit**
  - Large onboard data recorder; 1.7m Ka antenna for download
- **Calibration – need to understand systematics drove this**
  - Simplified relative calibration system built at GSFC is now integrated into the WFI

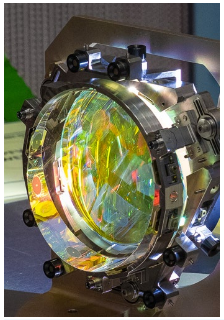
Technology development

- **Early funding for detector, grism and coronagraph technologies**
  - 10um pixel pitch and 4k format a new development, 18um, 2k used for (e.g.) JWST, Euclid
  - Detector readout ASIC ("ACADIA"), lower noise and easier to use/program
- **External review for detector and coronagraph early TRL milestones –**
  - History of all of this kept on project website roman.gsfc.nasa.gov
- **Successful, retiring much early technical risk**
- **Grism successful, EDU, ETU, mechanical model, flight**
- **After descope of IFC, added "simple" SN prism pair**
  - Some struggle developing this, but all elements delivered by late CY22
- **Launch loads and isolation system not deemed new technology**
  - Heritage from Honeywell "D strut" isolation system
  - Currently in flight fabrication, same-as-flight EDU nearing completion

Flight Elements installed on EWA



Flight Grism

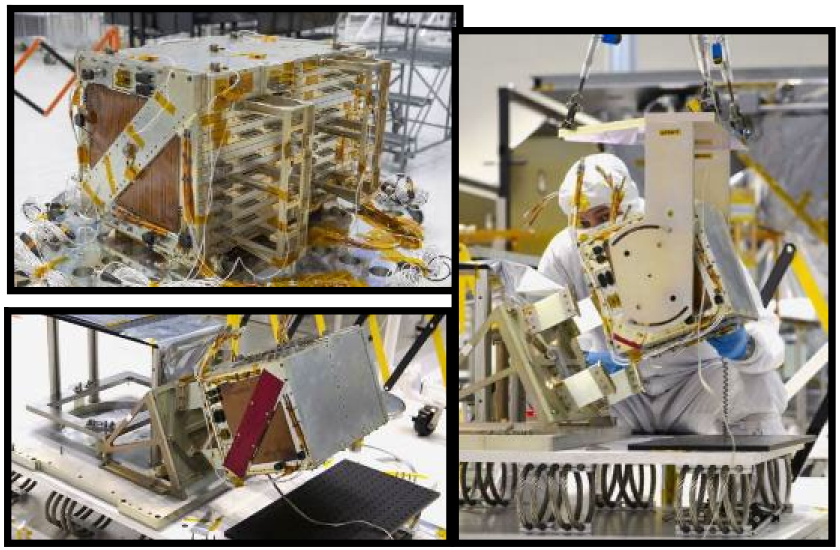


Flight Prism

Current status – Summer 2023

- Passed Critical Design Review (CDR) in September 2021
- Due to COVID and supply chain impacts, slipped launch readiness date 4 months to Oct2026
- Summer 2022, launch vehicle contract w/ SpaceX for Falcon Heavy
- All elements well into integration (instruments, telescope, instrument carrier, spacecraft), scheduled to deliver to observatory integration and testing during CY2024
  - Eg WFI including all optics, focal plane, electronics, are integrated, working on radiators now
- Observatory I&T ~2 years
- Formulation science teams concluded in 2021, new science teams recently announced

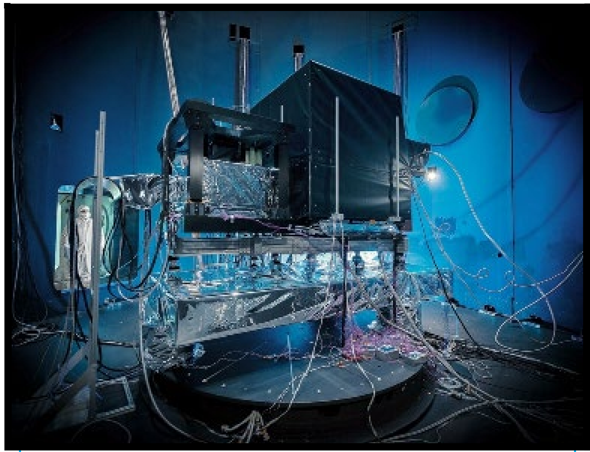
Wide Field Instrument Highlights



Focal Plane Electronics (FPE) assembly, thermal cycling, and vibration testing completed.

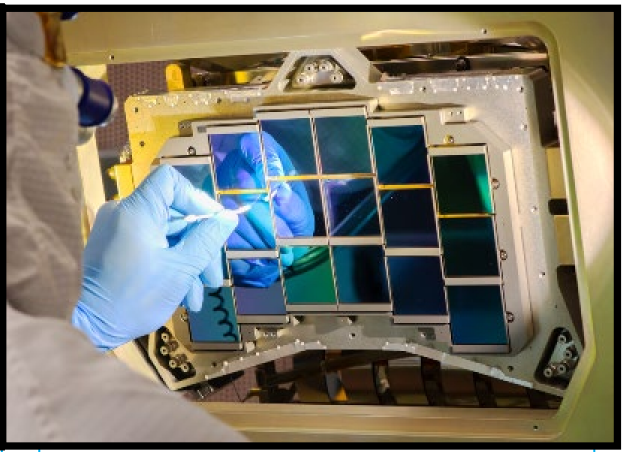
Focal Plane Assembly (FPA) after successful vibration testing. FPS assembly and thermal vacuum testing complete. FPS shipped to Ball in early May

WFI Hardware Deliveries



Stimulus of Ray Cones (SORC) Delivered to Ball

Simplified Relative Calibration System (sRCS) Delivered to Ball



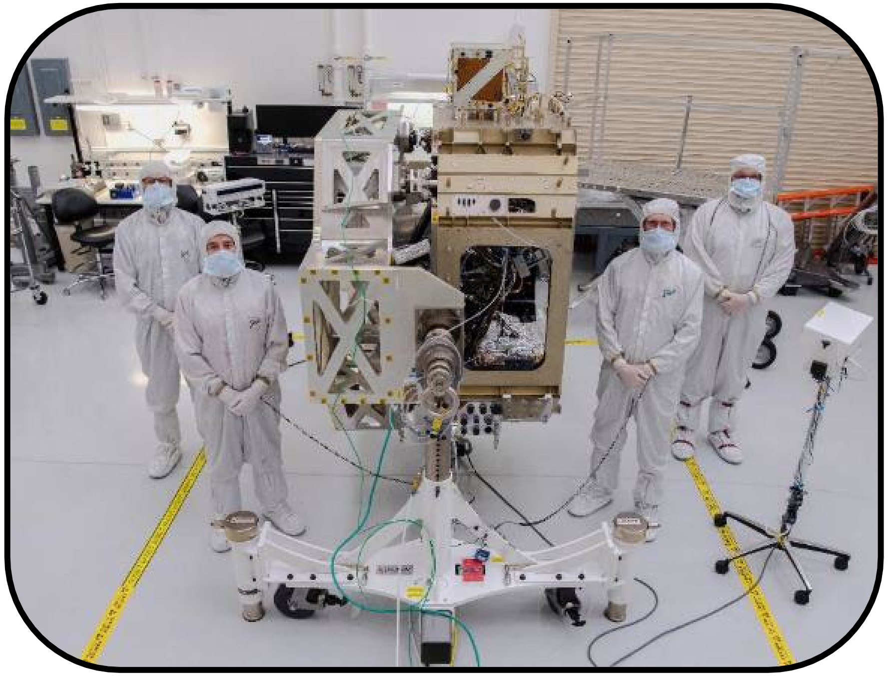
Focal Plane Assembly (FPA) Delivered to Ball

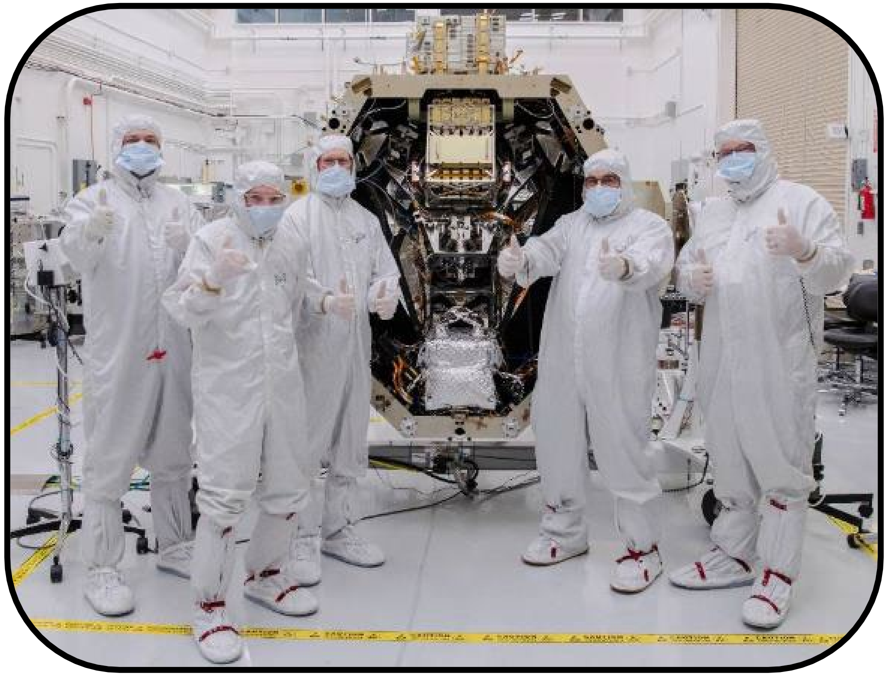
Focal Plane Electronics (FPE) Delivered to Ball

Goddard WFI Team

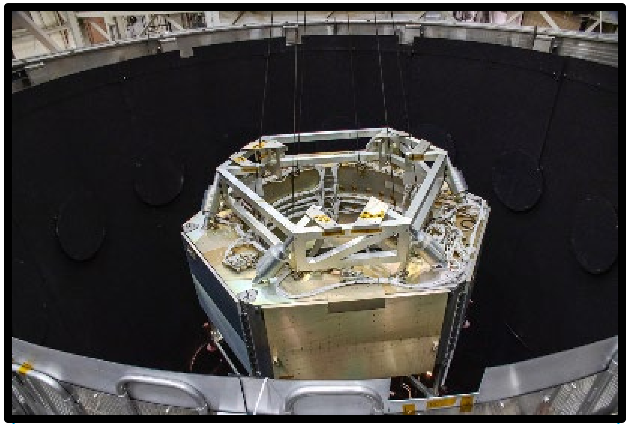
WFI Status and Accomplishments

WFI Focal Plane System (FPS) Mechanical Integration at Ball Aerospace

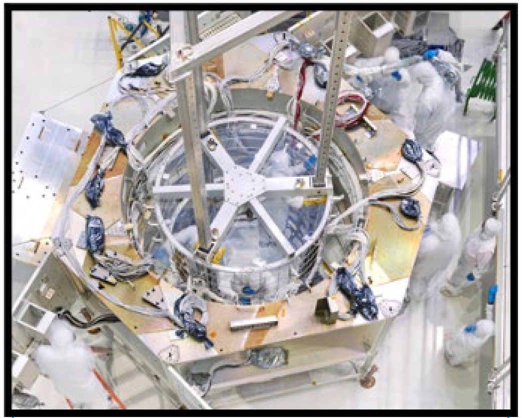




Spacecraft Highlights



Spacecraft Bus flight harnesses (on mockup) completed bakeout ahead of schedule.



Flight harnesses being integrated into Spacecraft Bus

Spacecraft High Gain Antenna System (HGAS) – assembly underway in SSDIF

Prop Deck Subassembly Lift to Prop Support Frame in B11 High Bay

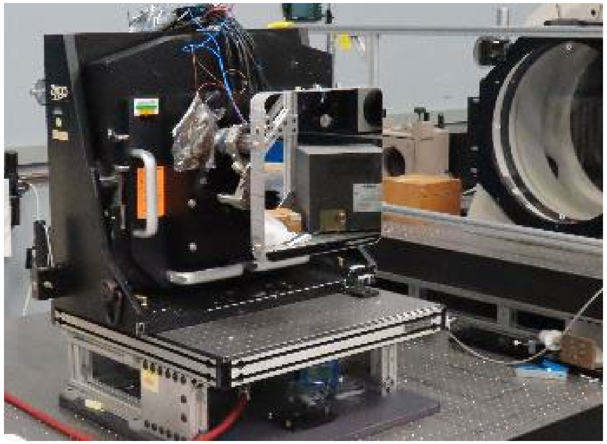
Spacecraft Solar Array Sun Shield (SASS) panels –
6 flight SASS substrate panels shipped to cell vendor in March for cell laydown

Telescope Highlights

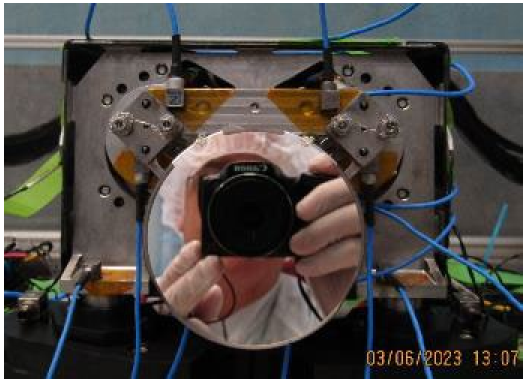
Recent Accomplishments

- ✓ Forward Optical Assembly completed
- ✓ Telescope Control Electronics (TCE) Assembly completed
- ✓ Tertiary Collimator Assembly (TCA) Optical Alignment completed

Completed Forward Optical Assembly



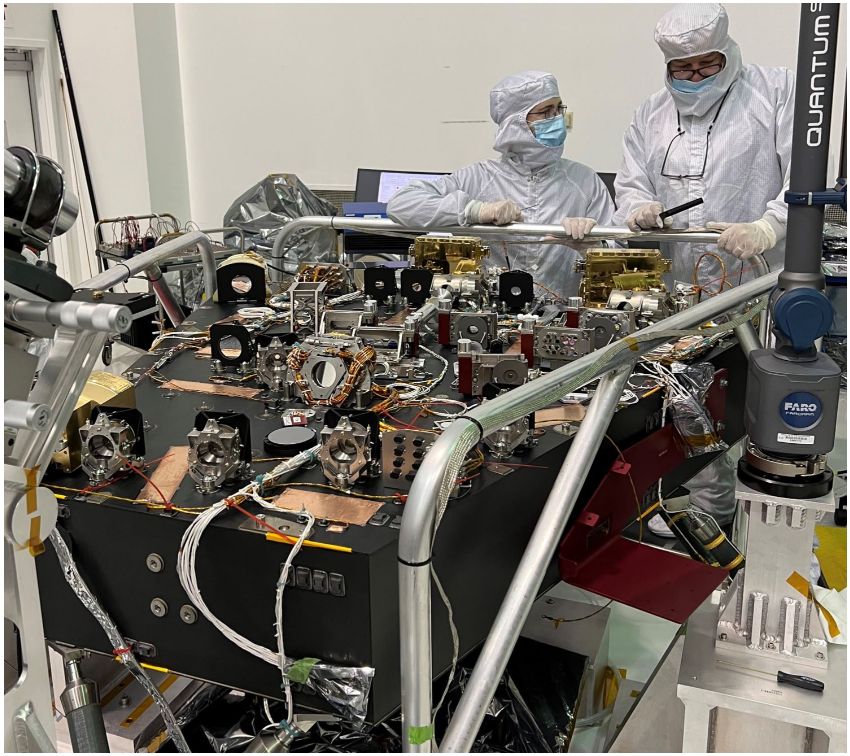
Completed Fold1 Assembly (in WFI feed)



Completed Tip/Tilt Fold Assembly (in CGI feed)

Instrument Carrier Structure & Coronagraph

- **IC Status and Accomplishments:**
  - Lower Assembly recently completed
  - Upper Assembly started
  - Delivery to GSFC I&T September 2023



- **CGI status**
  - **Optical bench fully populated & aligned**
  - **All electronics boxes through environments, completing electronics pallet**
  - **Instrument integration ongoing**

Backup

- **Thank you for your attention**

Optical, jitter suppression, thermal designs evolved over early design iterations