WFIRST/AFTA Telescope Overview

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Concurrent Astronomy Missions in the Next Decade- JWST, WFIRST, and SOFIA
American Institute of Aeronautics and Astronautics (AIAA)
Space and Astronautics Forum and Exposition (Space 2015)

Pasadena Convention Center

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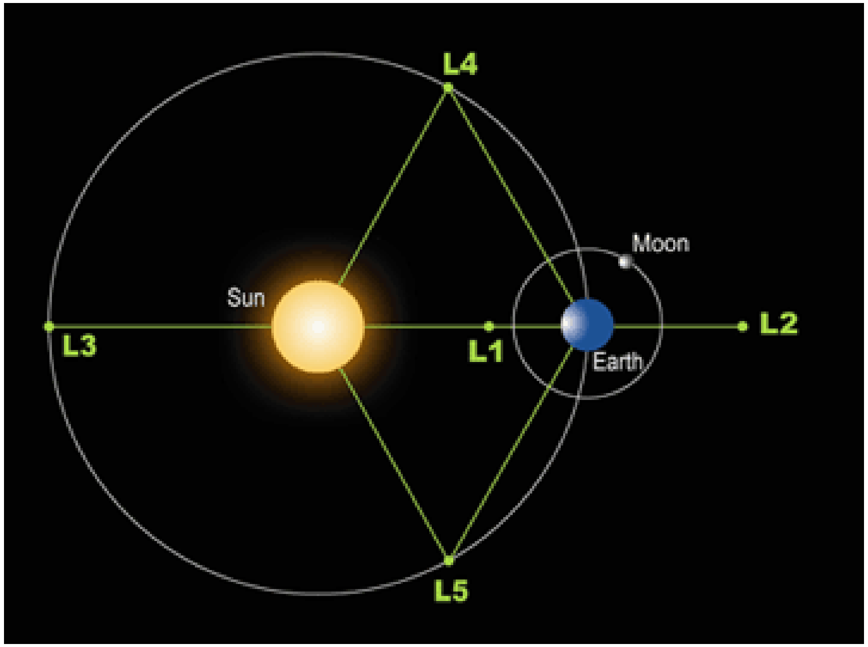
Telescope Summary

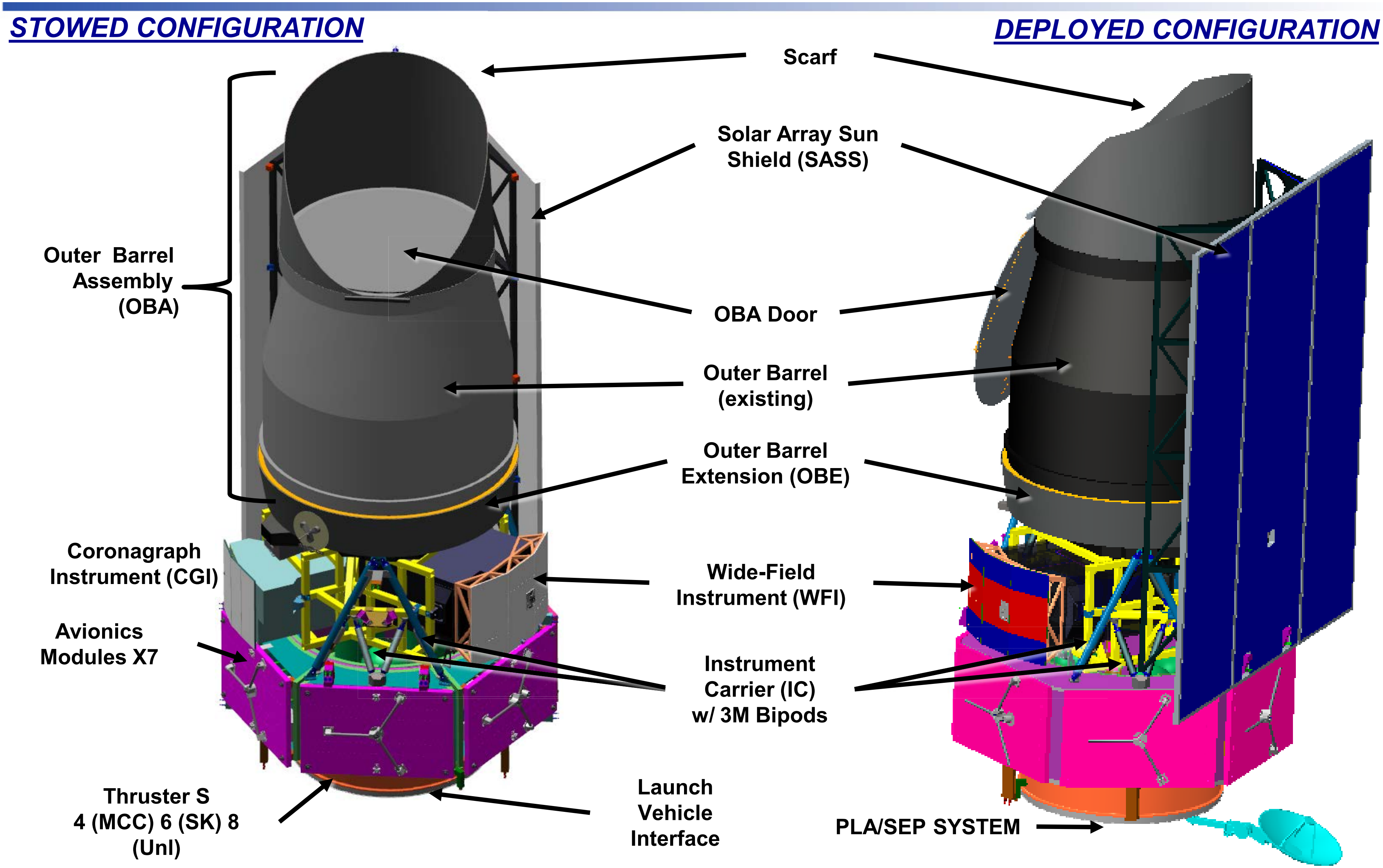
- The WFIRST Telescope is:
  - Inherited hardware, having been built over 10 years ago by what is now the Harris Corporation, Rochester, NY
  - 2.4 m diameter aperture
  - Includes primary mirror, secondary mirror, precision metering structures, and outer barrel assembly
  - Includes focus actuators, alignment actuators, and re-closeable doors on the outer barrel.
  - Includes active thermal control on the precision structure, thermally passive outer barrel
- Adapting this existing telescope to the needs of the WFIRST mission is the goal of the Telescope Subsystem

WFIRST Environment

- WFIRST Operating Environment
  - Was Geosynchronous Earth Orbit in 2015 SDT Final Report
  - Investigating change to Earth-Sun L2 orbit in the current design cycle.
  - Operating at L2 NOT official, but being investigated.
- Observatory at Earth-Sun L2 is more thermally stable than at GEO.
- This Telescope discussion is based on the current pre-formulation design cycle, not any official decision.



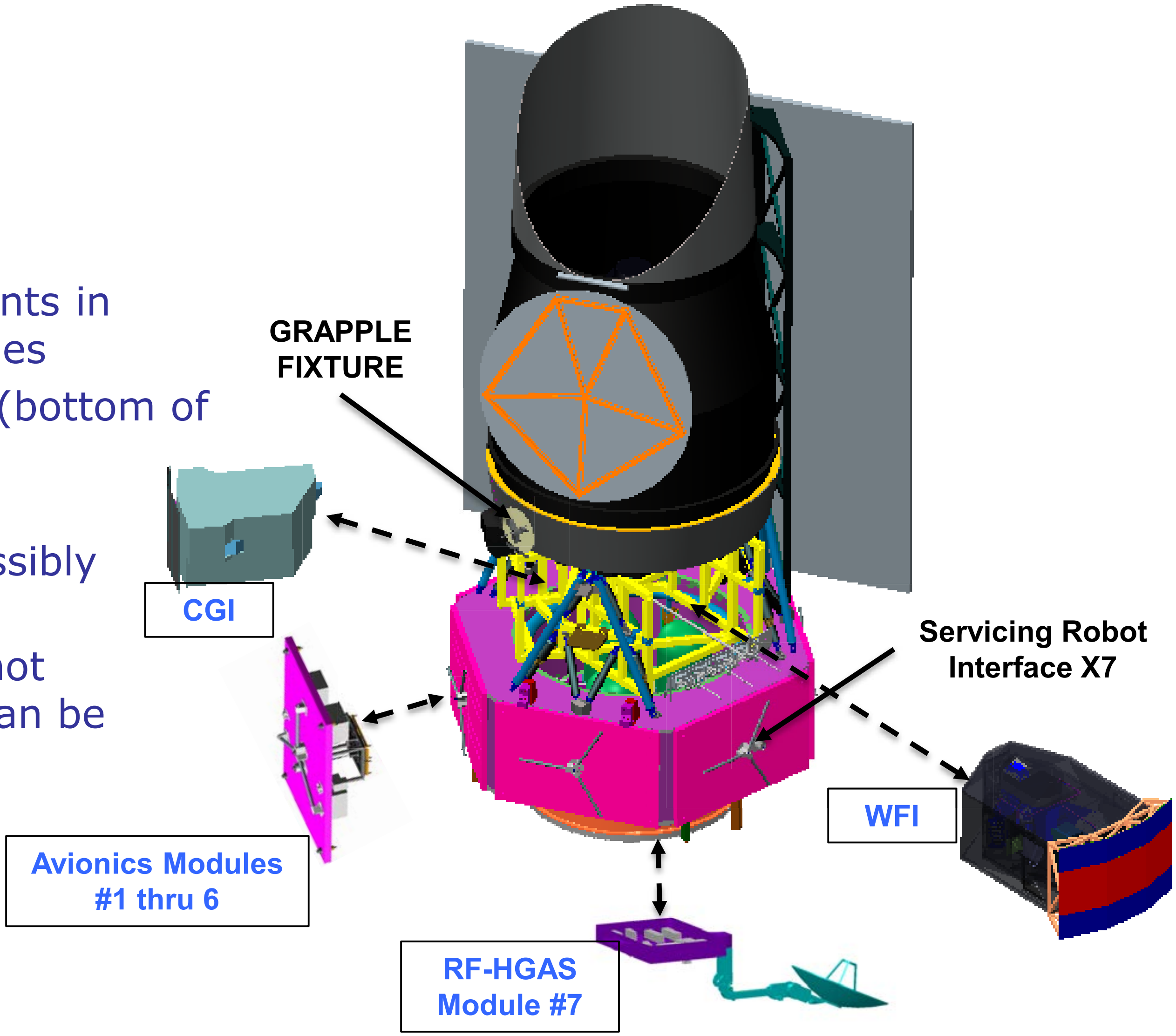
WFIRST Observatory Components



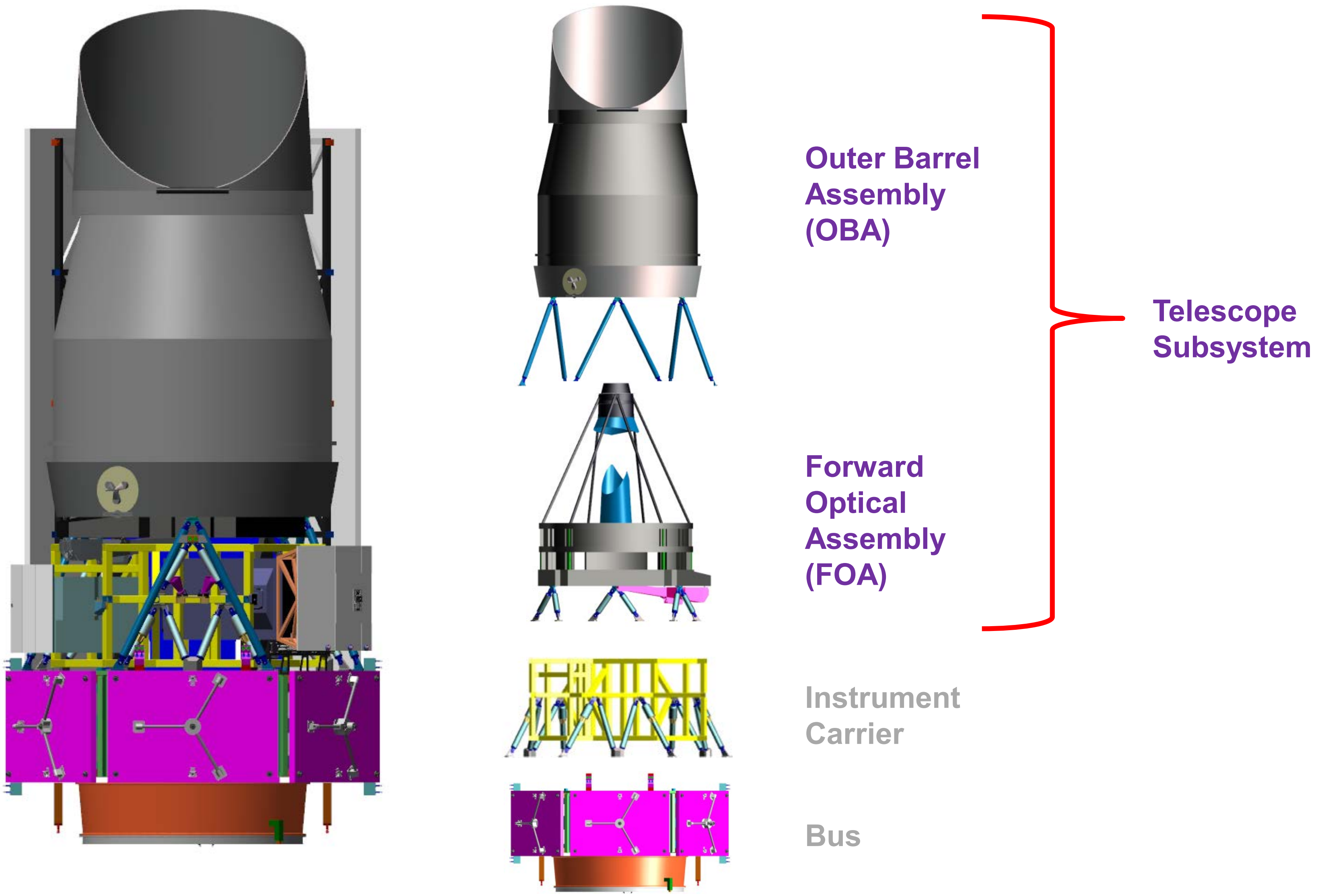
Servicing Components

Serviceable Components

- Instruments
  - WFI
  - CGI
- Spacecraft Components
  - Avionics components in serviceable modules
  - RF-HGAS Module (bottom of Spacecraft)
- Additional items
  - Star Trackers (possibly serviceable)
  - Propulsion Sys. (not serviceable, but can be refueled)



Telescope Subsystem



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Forward Optical Assembly (FOA)

Secondary Mirror Support Structure (SMSS)

Secondary Mirror (SM) (not visible)

PM and SM Baffles

Secondary Mirror Support Tubes (SMST)

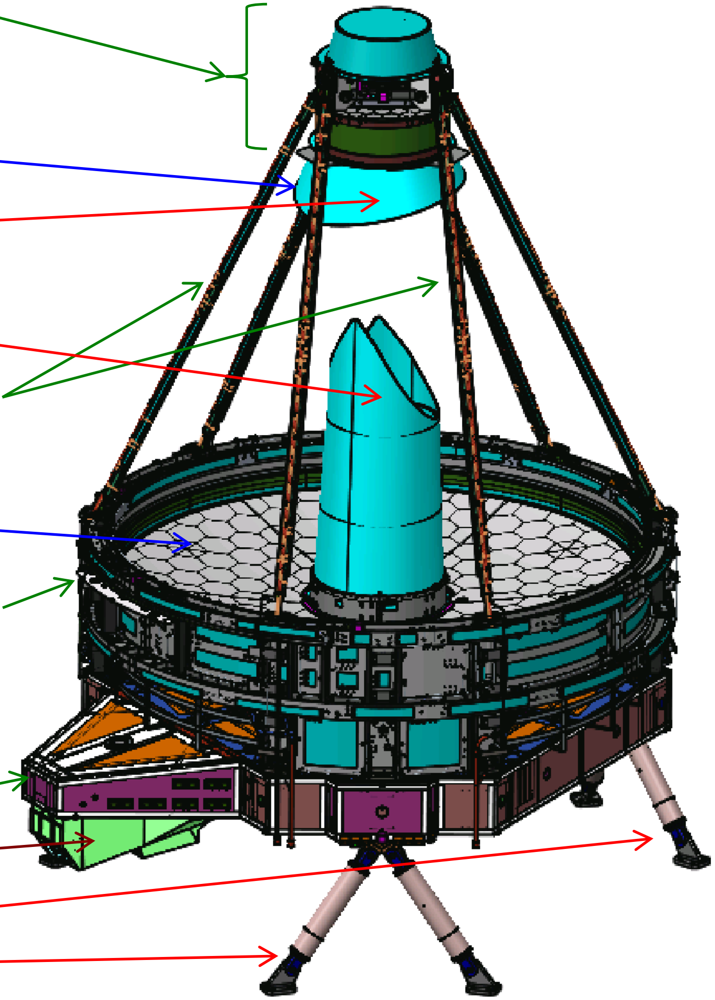
Primary Mirror (PM)

Forward Metering Structure (FMS)

Aft Metering Structure (AMS)

(Coronagraph Collimator) (not part of Telescope)

FOA Bipods



Re-use As-is

Modified Re-use

New Design

Forward Optical Assembly (FOA)

- The Forward Optical Assembly (FOA) is a precision structure that supports the Primary and Secondary Mirrors. Includes:
  - Aft Metering Structure (AMS)
    - Part of Primary Mirror Assembly (PMA)
  - Forward Metering Structure (FMS)
  - Secondary Mirror Support Tubes (SMST) – the “support struts”
  - Secondary Mirror Support Structure (SMSS)
    - Supports Secondary Mirror Assembly (SMA)
  - FOA bipods (interface to Instrument Carrier and part of precision metering structure)
  - Focus Drive Actuators (x2)
  - Alignment Drive Actuators (x6)

- Mass:
  - CBE FOA Mass: 1003 kg
  - CBE Telescope Control Electronics (TCE) Box: 60 kg

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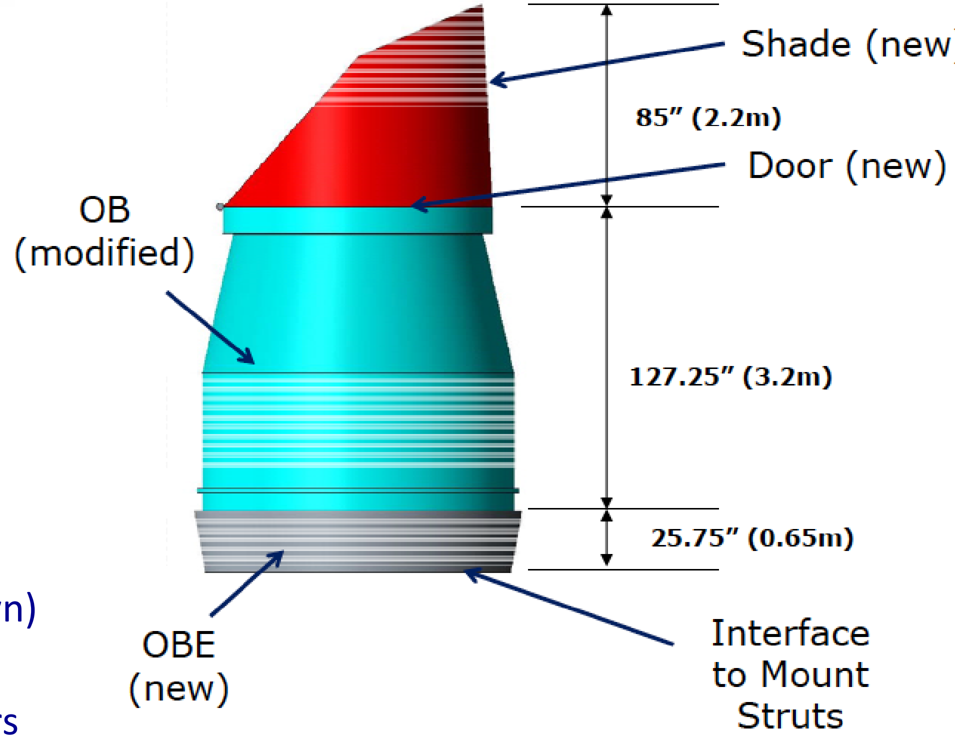
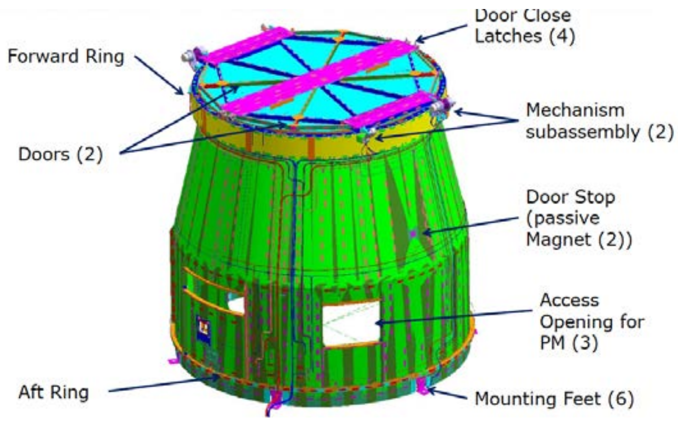
Outer Barrel Assembly (OBA)

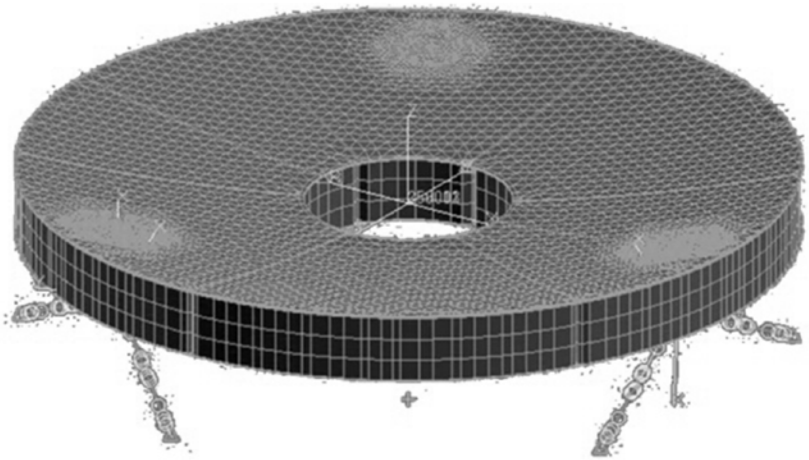
- Outer Barrel Assembly (OBA) provides stable thermal environment and stray light and contamination control
- Includes:
    - existing Outer Barrel Assembly (OBA) (unheated)
    - Shade
    - Outer Barrel Extension (OBE)
    - OBA bipods interface to S/C (not shown)
    - Single, re-closeable door
    - Full active thermal control with heaters (primary, secondary, survival)
    - Structural support for:
        - servicing grapple
        - omni-directional antenna
- CBE Mass (with contingency):
    - 470 kg (grapple & antenna not included)





Telescope Optical Design

- First two principal optics of:
  - Three Mirror Anastigmat (TMA) for the Wide-Field Instrument
  - Three Mirror Afocal Telescope for the Coronagraph Instrument
- Material: ULE®
- Optical Performance (fabrication): < 60 nm rms
- PM + SM: f/23
- Primary Mirror:
  - Clear aperture:
    - OD: 2367 mm
    - ID: 703 mm
- Secondary Mirror:
  - Clear aperture:
    - OD: 531 mm
    - ID: 25 mm



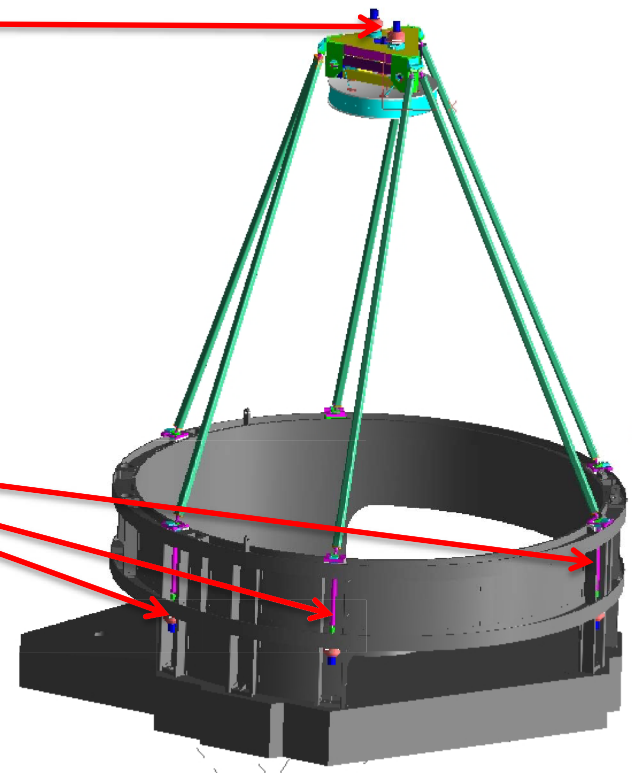
Telescope Structure

- Forward Optical Assembly (FOA) Structure
  - Primarily precision composite structure with invar and titanium fittings
    - Patented composite, “hybrid laminates” combined with low moisture uptake resins, has:
      - low Coefficient of Thermal Expansion (CTE),
      - low Coefficient of Moisture Expansion (CME)
      - high modulus
      - means low hygrothermal strain
  - Invar fittings at original instrument interfaces,
  - Titanium fittings at original interface to Spacecraft

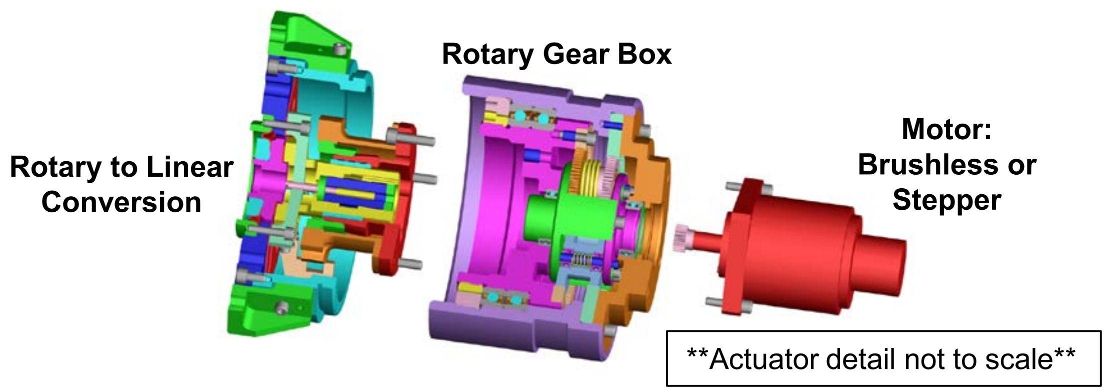
- Outer Barrel Assembly (OBA) Structure
  - Composite skins with Al honeycomb core
  - Structural rings and longerons as stiffeners
  - Titanium and invar fittings
  - Will support servicing grapple and omni-directional antenna

Actuators

- Focus Drive Actuator
  - 2 Actuators Under Thermal Shade
  - Bolted to Fitting on SMSS
  - Brushless Motor
  - Adjusts Fine Z Position of SM
  - Range: > 2 mm



- Alignment Drive Actuator
  - 6 Actuators Located between Longerons at base of SMST's
  - Actuators Bolted to Fittings on Aft Ring
  - Stepper Motor
  - Adjust X, Y, θX, θY, & coarse Z position of SMA
  - Range: > 1 mm



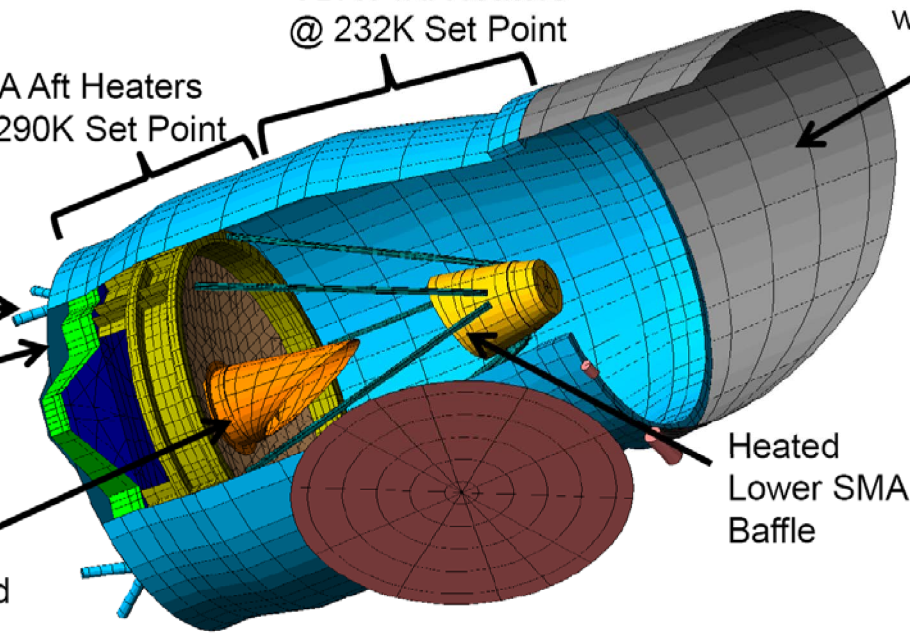
Telescope Thermal Control Design

- Independent primary, secondary, and survival heater traces on the FOA and OBA
- OBA active thermal control provides stable environment for FOA and to supplement heating by radiation.
- On FOA, heaters provide active control of:
  - AMS, FMS, SMSTs, SMA, and FOA bipods (all metering structures)
  - All actuators
- No existing heater control electronics
- Planned use of Harris commercial heater control boards for WFIRST

Telescope Thermal Control Design

- Baseline 282K operating temperature (FOA structure)
- Operation within qualified temperature range of both FOA and OBA
- Use of primary heater trace only @ 70% duty cycle
- Control telemetry for each heater zone
- Total Power: 1380W
  - OBA: 1179W
  - FOA: 201W (includes new baffles & struts)

Component	Power, W	Heater Capacity, W	Duty Cycle, %
AMS	23.7	117.4	20.2
FMS	35.0	114.3	30.6
SMA	13.2	28.9	45.7
SMST	36.1	117.7	30.7
FOA Total	**108.0**	**378.3**	28.5
PM Baffle	44.2	300.0	14.7
SMA Baffle	15.7	75.0	20.9
FOA Struts	32.4	240.0	13.5
OBA	1179.3	7520.0	15.7
Tele Total	**1379.6**	**8513.3**	**16.2**



FOA (AMS, FMS, SMST, SMA, & FOA Strut) Heaters @ 282K Set Point

Telescope Activities

- Yes, Telescope exists…however,

- It must be adapted to the operating environment at Earth-Sun L2 orbit and needs of WFIRST:
  - L2 environment is more thermally stable than at GEO.
  - Modify optical prescription as appropriate for Wide-Field Imager and Coronagraph Instruments
  - Modify OBA for thermal stability and stray light control
  - Serviceability of Telescope electronics
  - Desired lower operating temperature
- Investigations include:
  - Inheritance Review of existing hardware
  - Operating temperature capability assessment
  - Analysis of FOA optical performance and stability during observing scenarios.
  - Structural analysis with respect to different launch loads and temperature environments.

Inheritance Review

- Review of pedigree documentation and make recommendations regarding required tests to bring any use “as-is” hardware to NASA standards. *(almost complete)*

- Review pedigree documentation of hardware to be modified, and make recommendations as to required activities to qualify modified hardware (includes Primary and Secondary Mirrors)

- Review capabilities of build-to-print hardware, and compare to WFIRST requirements.

- Review all inherited hardware/designs and compare to WFIRST requirements

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Operating Temperature Assessment

- Mandate from HQ to assess the risk of operating the Telescope (FOA) at a temperature below its qualified range:
  - Minimum qualified survival temperature: 277K
  - Current baseline operating temperature: 282K
- Lower temperature desired by scientists to reduce thermal emissions up to 2.4μm wavelength (WFI detector cutoff)
  - as low as 250K telescope operating temperature desired
- Investigations include:
  - Material property characterizations (temperature dependent) of composite laminates, lamina, and adhesives by coupon fabrication and testing
  - Breakout model development and analysis of bond joints using temperature dependent material properties
  - Load testing of pathfinder development units (aged) to test bond joints after thermal cycling
  - Optical performance Cool Test to validate temperature dependent structural models
- Investigations in progress, expected completion Q4 FY2016

Other Risk Reduction Activities

- Other risk reduction activities include:
  - Hardware aging assessment (hardware over 10 years old, another 9 years to launch)
  - Condition of Ground Support Equipment (GSE) and Special Test Equipment (STE)
  - Inventory and catalog all existing pedigree documentation
  - Plan Assembly, Integration, and Test procedures in accordance to NASA guidelines and WFIRST Payload plan
  - Assess build-to-print electronics for WFIRST use
    - Are any components obsolete?

Acknowledgements

- WFIRST Telescope Subsystem:

@ JPL:

  - Ben Parvin
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  - Robert Egerman
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  - Mark Melton
  - John Ruffa
  - Lisa Bartusek
  - Jeff Stewart
  - Cory Powell
  - Hume Peabody
  - Bert Pasquale

- And many others….

Thank you!