Overview of the Gondola for High Altitude Planetary Science (GHAPS)

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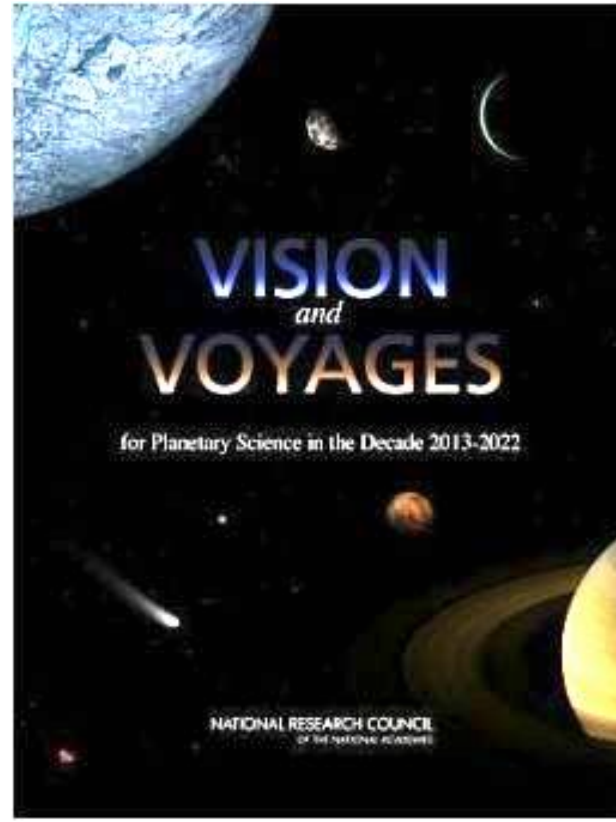
Background

- The GHAPS project resulted from the 2011 Decadal Survey describing balloon-based planetary science as a high priority to enable achievement of long-term planetary goals.
- In January 2012, GRC led a workshop to assess the potential of planetary science missions from a balloon-based observatory laying the ground work for the GHAPS concept (Final Report - NASA/TM—2016-218870).
- Super-pressure balloon development has increased the planetary science potential for a balloon based observations.
  - Enabling missions up to 100 days with day/night cycles from Wanaka New Zealand.
- GHAPS Mission Concept Review (MCR) and System Requirements Review (SRR) were successfully completed in December 2015.



Outlines plans for space and ground based exploration ten years into the future

GHAPS Goals and Objectives

GOALS		OBJECTIVES	
1.0	Collect decadal-class planetary science from a balloon-borne platform, with particular emphasis on observations not practical or possible from the ground, or airborne/space-based assets.	1.1	Observe planetary objects in the UV, visible, near to mid-IR spectrums (approximately 0.3 to 5 µm wavelengths).
		1.2	Point to and track planetary targets with sub-arcsecond accuracy.
		1.3	Observe planetary targets for several hours up to 100 days.
2.0	Reduce the cost and time required for development of balloon-borne planetary science missions.	2.1	Fly balloon-borne planetary science missions at a frequency of once per year.
		2.2	Successfully complete 5 flight campaigns with refurbishment costs for each less than 20 percent of the original hardware development cost.
3.0	Provide a balloon-borne platform to support a broad envelope of planetary science mission needs as described in the Decadal Survey.	3.1	Provide a platform with standardized interfaces and functional characteristics for instrument packages that meet an envelope of balloon-borne planetary science mission needs.
		3.2	Provide an adaptable platform for conventional, long duration, and ultra-long duration missions through the Columbia Science Balloon Facility.

Main Drivers

Key drivers for balloon-borne investigations:

- » **Access to wavelengths that are inaccessible** with ground-based telescopes
- » **Temporal coverage**
- » **High spatial resolution** at short wavelengths and **high spectral resolution** from UV to IR wavelengths
- » **Science trades focused on maximizing the # of Decadal Science questions addressed**
- » **Clear break points between increased cost and incremental science return**
  - – **1 m Aperture**
  - – **Sub-arcsecond coarse pointing stability**
  - – **Float altitude ≥ 100k ft**
- » **Presented these parameters with other expected conditions to SIDT**
  - – **SIDT evaluated the platform for science ability**
  - – **SIDT evaluated the types of instruments suitable to capture diverse science objectives**

Key results from SIDT

- The **capability to track objects at non-sidereal rates** is critical for many solar system targets
- Sensitive IR detectors require temperature of ~30 K

Imaging

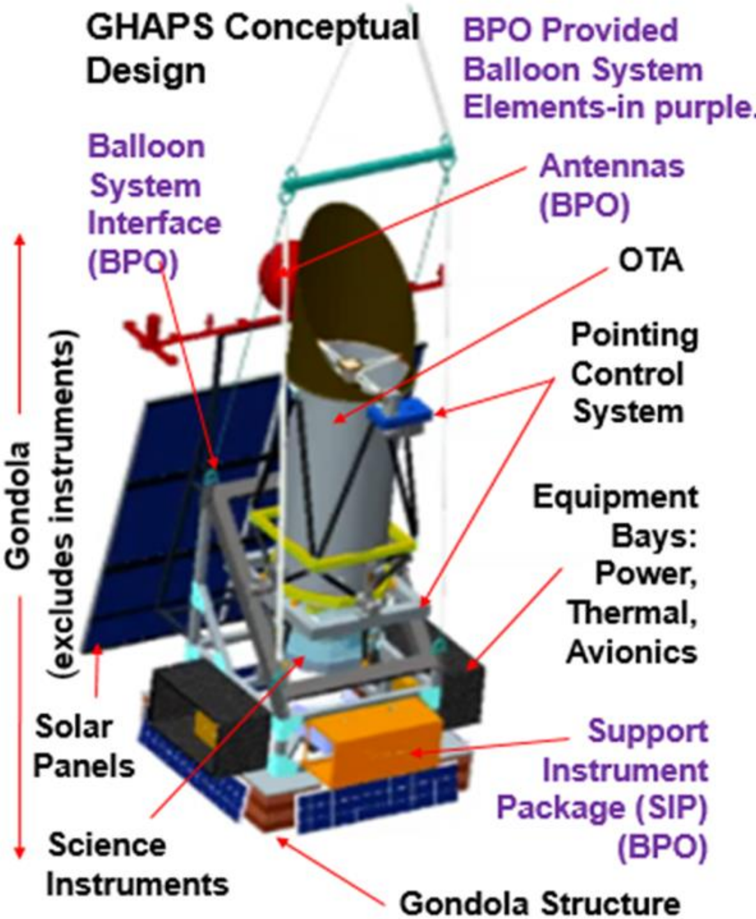
- A fine guiding capability (**jitter < 30 milliarcsec RMS**) is critical for a number of measurements, particularly at UV and visible wavelengths
- High image acuity (i.e. **diffraction-limited imaging**) over all wavelengths, and a **field of view of at least 3'**

Spectroscopy

- A range of desirable instrument modalities, including **long slit (>10") spectroscopy** for both UV and IR
- Two dimensional spectroscopy (integral field unit or hyperspectral imaging)

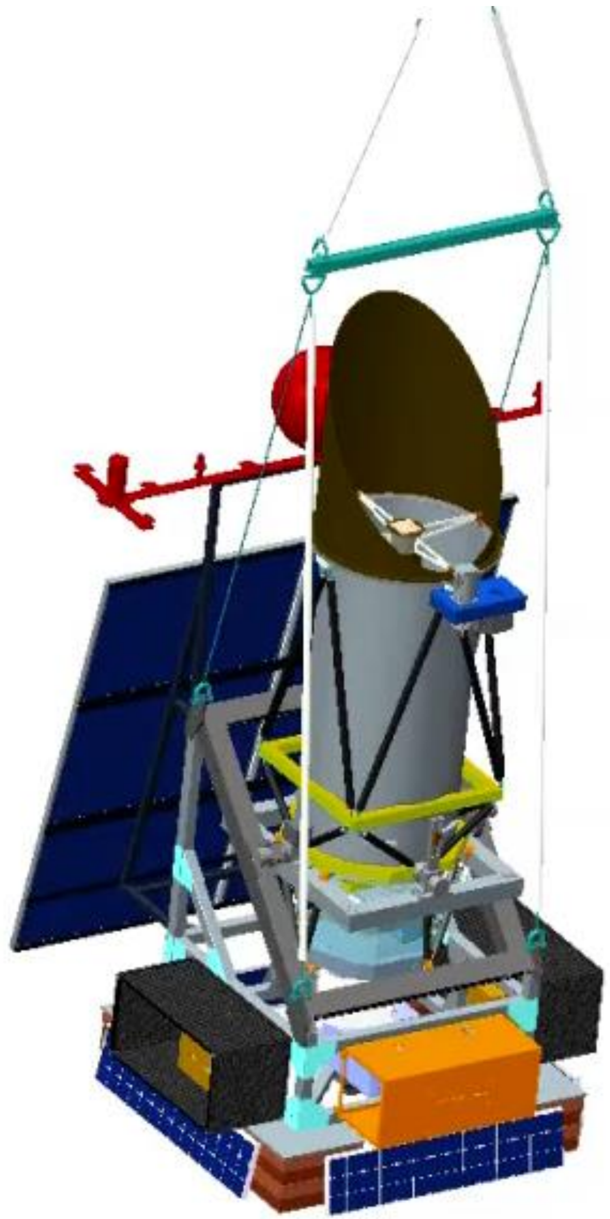
GHAPS Overview

- Develop a Re-useable Balloon Platform to meet Planetary Science Goals and Objectives as outlined in Decadal Survey
- 1 meter Optical Telescope Assembly (OTA) with Sub-arc-second pointing capability
- Designed for a minimum of 5 flights from any Balloon Program Office (BPO) launch location
- Designed for mission durations up to 100 days
- Planetary Science Observations 300-5000 nm
- Low cost refurbishment between flights
- The first flight is planned for Fort Sumner, New Mexico in the fall of 2019
- The objective of the first flight is to demonstrate performance and conduct science observations
- A competitive process will be used to select investigators and the GHAPS Instrument Suite.

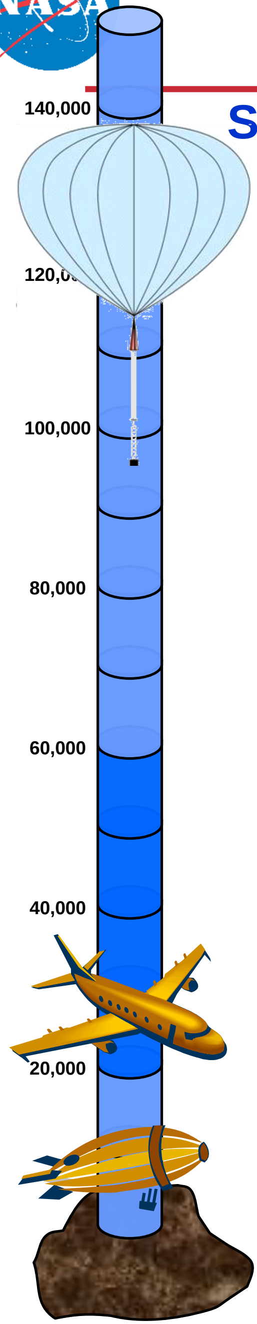


GHAPS Challenges

- Operating in Gravity field
  - If space-based, gravity wouldn't be an issue – structure could be made lightweight
  - If we were ground-based, weight wouldn't be an issue so structure could be made stiff
  - Our requirement is to be stiff yet light
- Dual Wavelength (UV-Vis and IR)
  - Conflicting thermal requirements for the combined single-mission with no active cooling
    - UV-Vis diffraction limited performance at -30 °C
    - IR observations at -50 to -60 °C
  - Mirror coating selection for high reflectivity and low emissivity across wide spectral range (.3 to 5 μ)

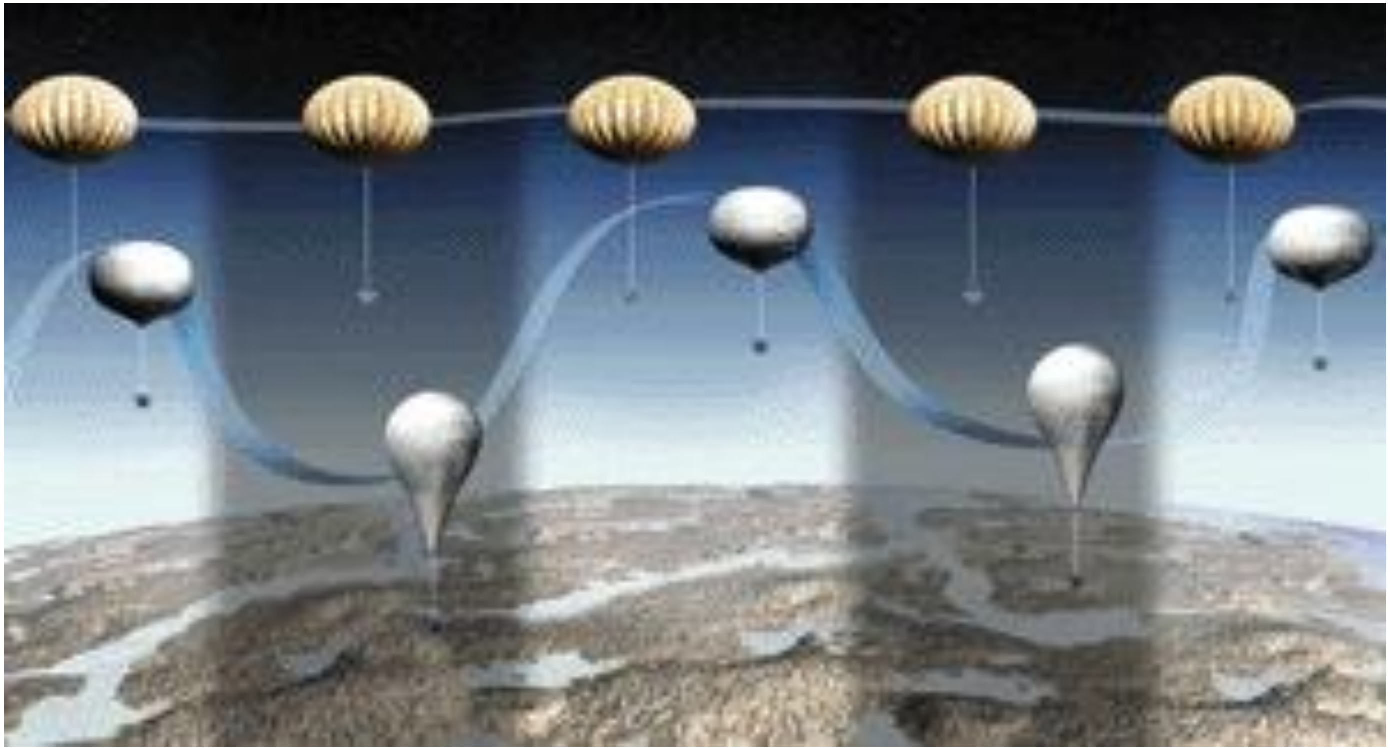


Two Types of Balloons



Super-Pressure Balloon maintains nearly constant volume

- Allows Ultra Long Duration Balloon (ULDB) Flights
- Provides stable altitude Long Duration Balloon (LDB) flights at mid-latitudes



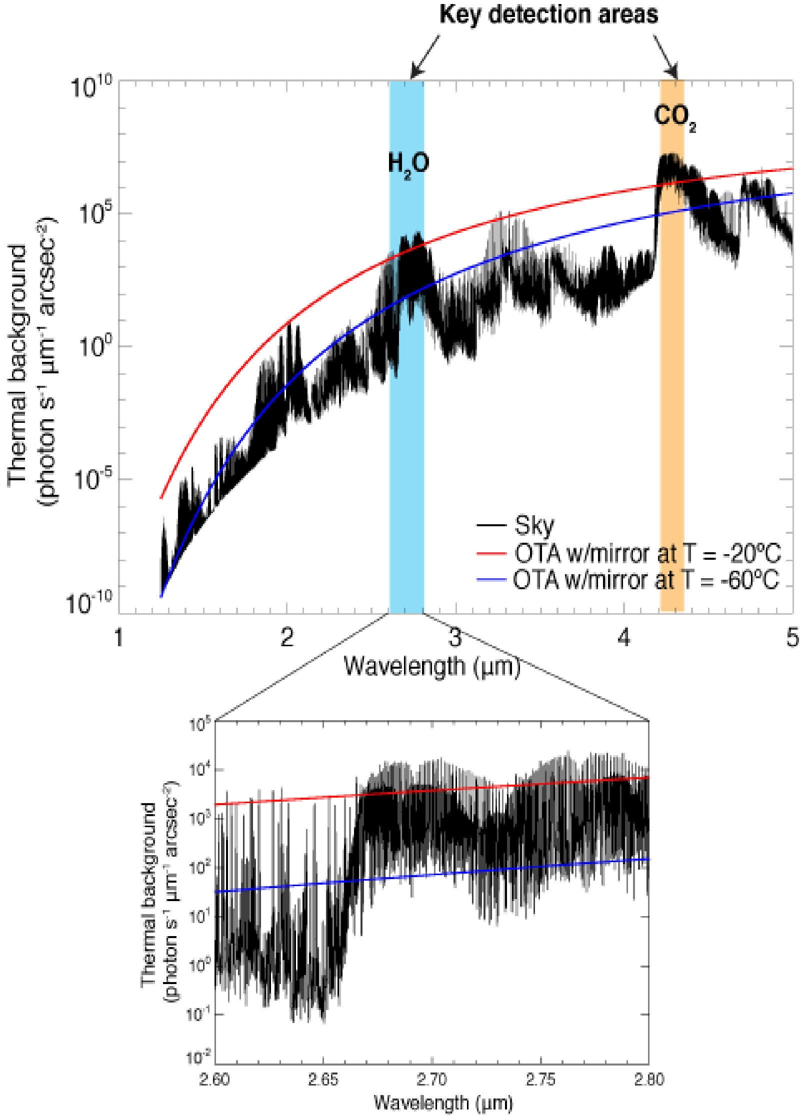
Zero-Pressure Balloon changes volume due to temperature changes

- Used for Conventional Flights and Polar LDB Flights

GHAPS Partners Provide Key Subsystems GHAPS Project Science Team and Software

GODDARD SPACEFLIGHT CENTER (GSFC)

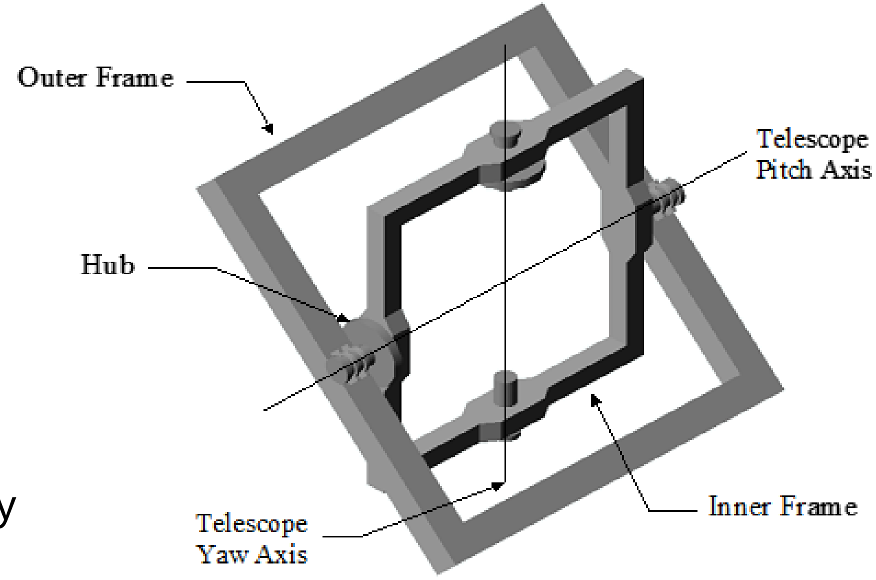
- The GHAPS Project Scientists reside at GSFC.
  - The project scientists translate science goals into science requirements,
  - develop design reference mission scenarios as part of GHAPS development cycles,
  - assist in mission design and operations strategy,
  - support development of instrument calls and science mission call for proposers,
  - set up the GHAPS data processing and distribution system,
  - coordinate with potential and active users and identify future platform improvements to increase science return.
- GHAPS Flight Software Lead resides at GSFC
  - Responsible for management, development, test, and flight support of the flight and mission operations software for GHAPS.



GHAPS Partners Provide Key Subsystems
Wallops Arc-Second Pointer (WASP)

WALLOPS FLIGHT FACILITY (WFF) - GSFC

- WFF selected based on analysis of RFI responses and HQ review held October 2015.
- In-house build and test planned at WFF
- GHAPS/WASP simulations predict sub-arc-second pointing is achievable



Scope:

- WASP development, test, qualification, assembly integration and test support, flight support. (In – House)
- WASP Sustaining engineering, including refurbishment between flights
- WFF to provide support for integrated testing and mission operations
- The WASP is controlled and monitored from a control center at the NASA Wallops Flight Facility (WFF).

Updates since MCR/SRR:

- XL Design provides ~1.2 meter clearance and has embedded hubs to eliminate counterweights

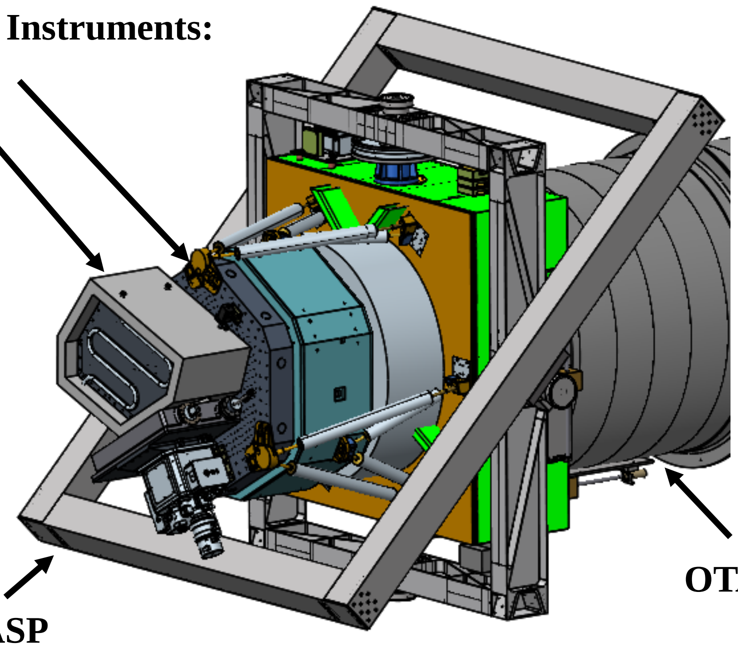
FEATURES:

- Sub-Arc Second pointing capability
- 815 lb mass allocation
- Fine instrument pointing achieved using gondola mounted pitch/yaw gimbal
- Outer Frame incorporated into Gondola Structure
- Inner Frame and star tracker interface with OTA.
- Gimbal Frames support Hub and Maintain alignment.
- LN251 Fiber Optic Gyro
- WASP Avionics

GHAPS Partners Provide Key Subsystems Infrared, Ultraviolet and Visible Instruments

INSTRUMENT APPROACH:

- Two instruments are being used as design reference mission instruments (300-5000nm wavelengths).
- Science Instrument Definition Team (SIDT) organized by HQ to define and prioritize science instruments for GHAPS.
- Preliminary report has been released and is currently under review – September, 2016.
- HQ call for instruments – October Release
- NASA GRC to manage instrument development.



Scope:

- Instrument developer responsible for development, test, qualification, assembly integration and test support, flight support.
- Instrument Sustaining engineering and refurbishment between flights
- Instrument developer to provide support for integrated testing and mission operations

DESIGN REFERENCE INSTRUMENT FEATURES:

UVVis

- UV and Visible instrument (300–700 nm) (includes fast steering mirror) developed by Southwest Research Institute (SwRI)

BRISSON IR Camera (BIRC)

- Near to mid IR instrument (2.5–5 microns) developed by APL

GHAPS Partners Provide Key Subsystems Optical Telescope Assembly

MARSHALL SPACE FLIGHT CENTER (MSFC)

- MSFC selected based on RFI responses.

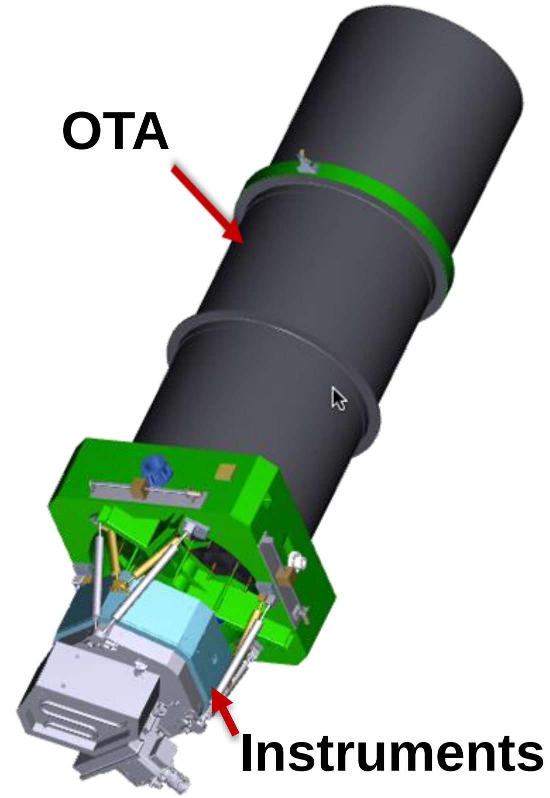
Scope:

- Optical Telescope Assembly (OTA) development, test, qualification, assembly integration and test support, flight support. (In – House)
- OTA Sustaining engineering, including OTA primary mirror recoat and refurbishment between flights
- MSFC to provide support for integrated testing and mission operations

Updates since MCR/SRR:

- Addition of Shack-Hartmann wavefront error sensor for OTA secondary mirror control
- Tailored OTA primary mirror zerodur for improved UVVIS performance at cold temperatures.
- Instrument-OTA integration at MSFC - Xray Cryogenic Facility (XRCF) for coupled environmental optical alignment test.

OTA PDR – 10/27/16

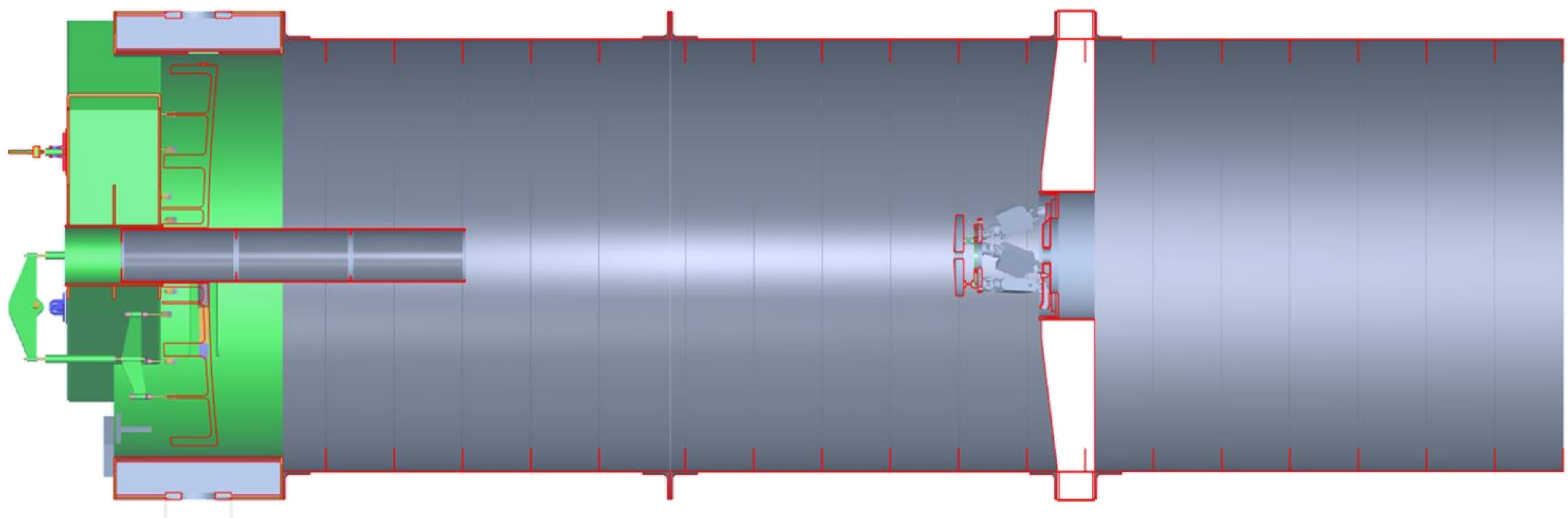


FEATURES:

- 14.056-m focal length
- 1-m clear aperture
- 632 lbs weight allocation
- Ritchey–Chrétien design
- Metering structure - composite, IM7-8552, with metallic inserts at high stress points
- 0.3 – 5 µm pass band

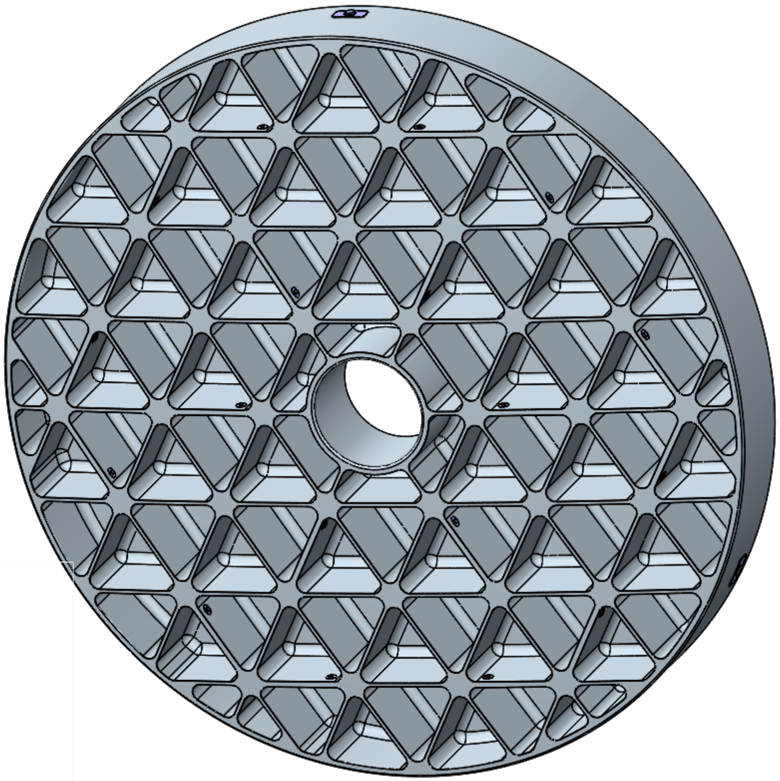
OTA Characteristics

- 14.052-m effective focal length (EFL) Ritchey-Chretien (RC) design
- Hyperbolic primary and secondary
  - Primary will be a contracted item – size exceeds in-house fabrication capabilities
  - Secondary will be fabricated in-house (fall-back is to contract)
- Design influenced by existing UV-visible and IR instruments
- OTA focal length is a compromise between short focal length desired for IR instrument and long focal desired by UV-visible instrument
- **Primary Mirror procurement:**
  - **https://www.fbo.gov/**



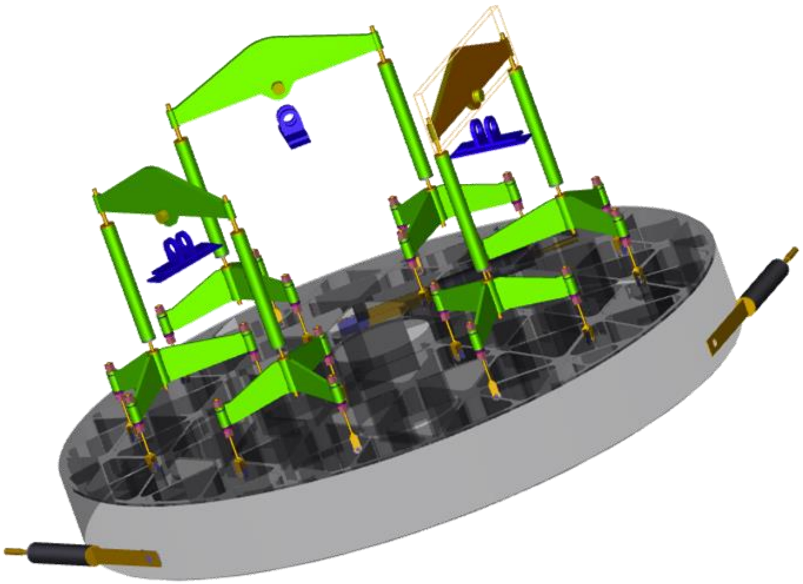
Primary Mirror and Supports

Primary Mirror:



Mirror Support

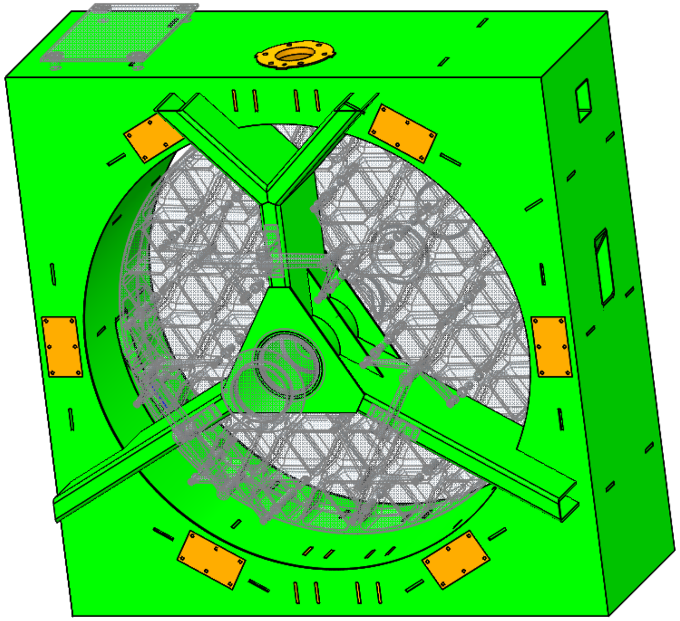
- Athermalized Whiffletree and Tangent Bar mounts
- Mount members sized to match secondary mirror despace

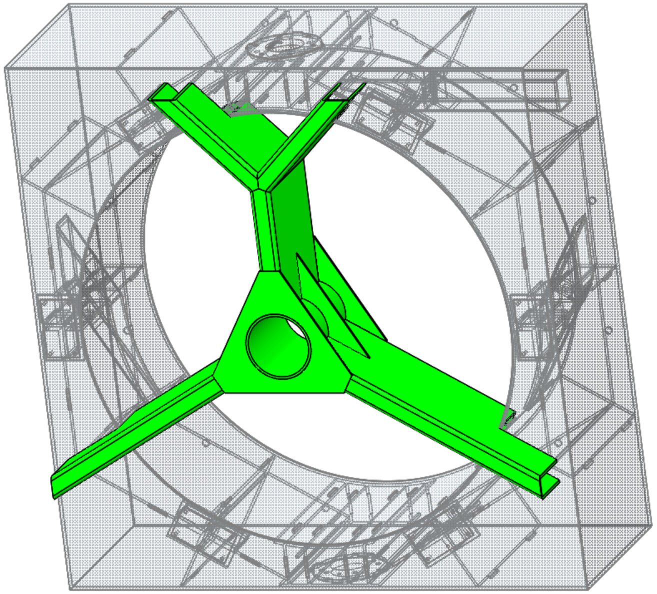


(M1) Composite Cell

- **(M1) Box Frame**
  - **39-Piece Composite**
  - **2 WASP Interface Hubs**
  - **6 Datum A Interface Pads**
  - **3 Tangent Bar Mounting Plates**

- **(M1) Cruciform**
  - **9-Piece Composite**
  - ***Interface Hardware***
    - ***Plates, (M1) Whiffle-Tree***
    - ***Pins, (M1) Light-Baffle***



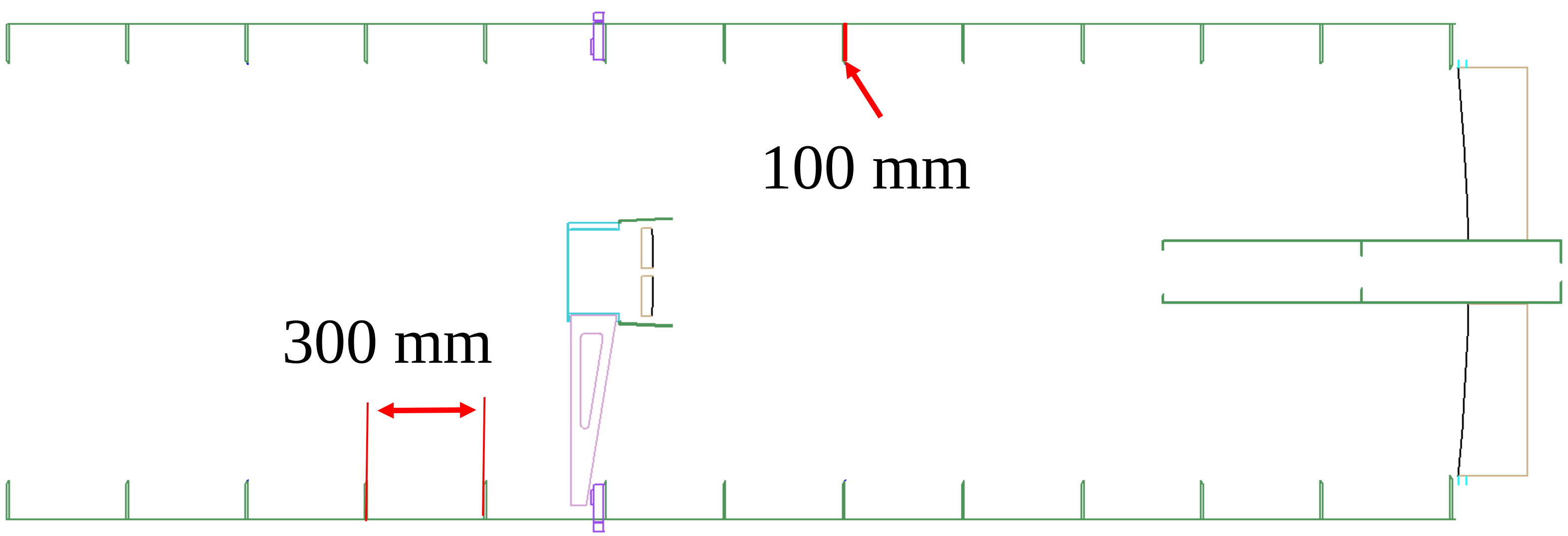


Metering Structure and Light Baffle

» **M1 & M2 Metering Tubes**
- **Composite barrel, with molded flanges (bonded to structure)**
- **16-Ply, .115" Thick**

» **Light-Baffles**
- **Composite Sheet**
- **8-Ply, .058" Thick**

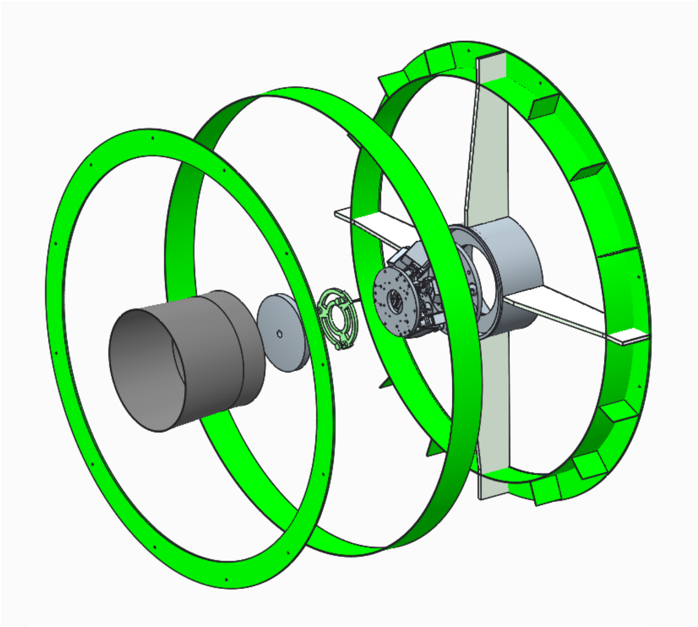
» **Sunshade Shroud**
- **50" Length**
- **46" ID**
- **IM7/8552 Carbon Fiber**
- **8-Ply, .058" Thick**



Secondary Assembly

Composite Sheet head Ring

- IM7/8552 Carbon Fiber
- 32-Ply, .230" Thick
- 16-Ply, .115 Thick radial supports

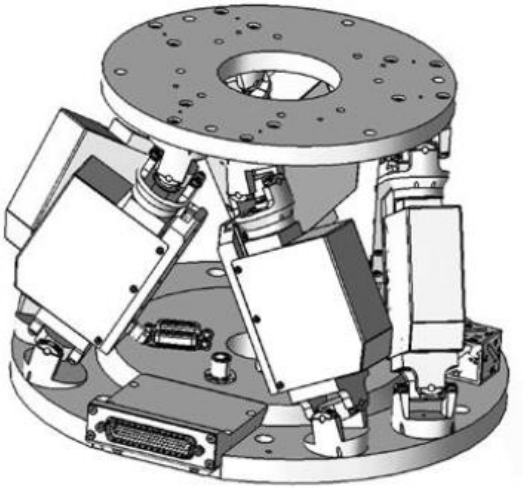


Secondary Mirror

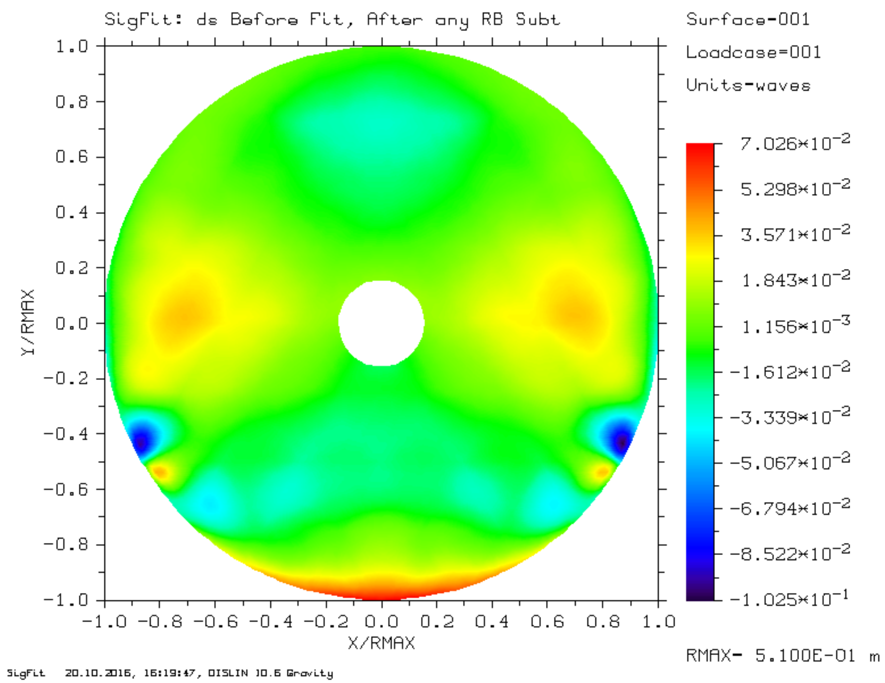
- 220 mm OD
- 25.95 mm Thick
- Zerodur

PI H-824K023 Hexapod

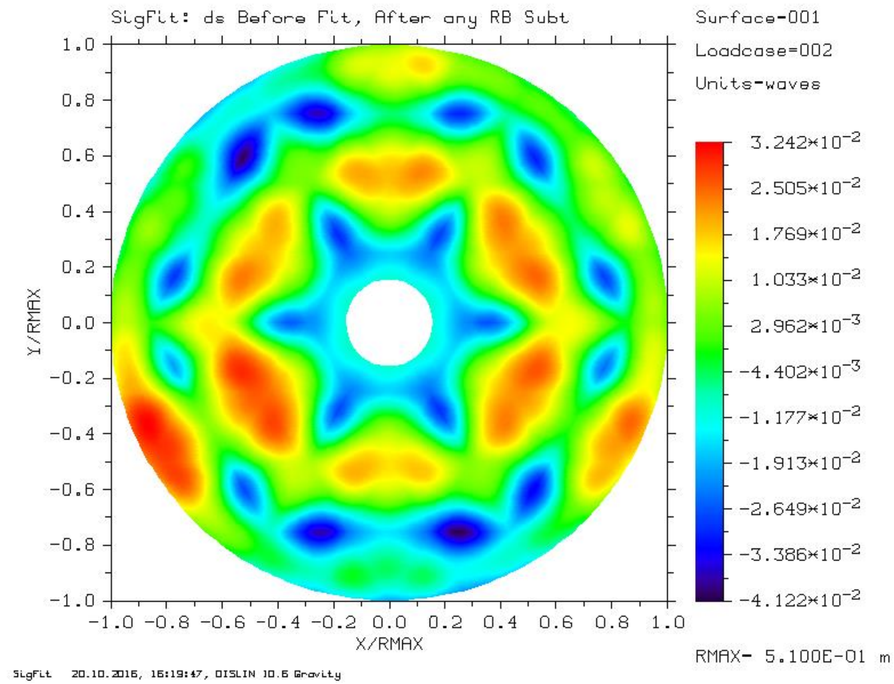
- Travel +/-12.5 mm (X,Y), +/- 22.5 mm (Z)
- Tilts +/- 7.5° (X,Y), 12.5° (Z)
- Minimum X,Y,Z motion increment 0.3 µm
- Minimum tilt increment: 3.5 µrad
- 10 kg load (self-locking feature)
- Vacuum compatible to 1 x 10^{-6} torr
- Motor type: Brushless DC
- Operating temperature range: 0 to 50 C



Primary Mirror (PM) Gravity Error



SFE when pointing horizontally; defocus removed; 632.8nm waves

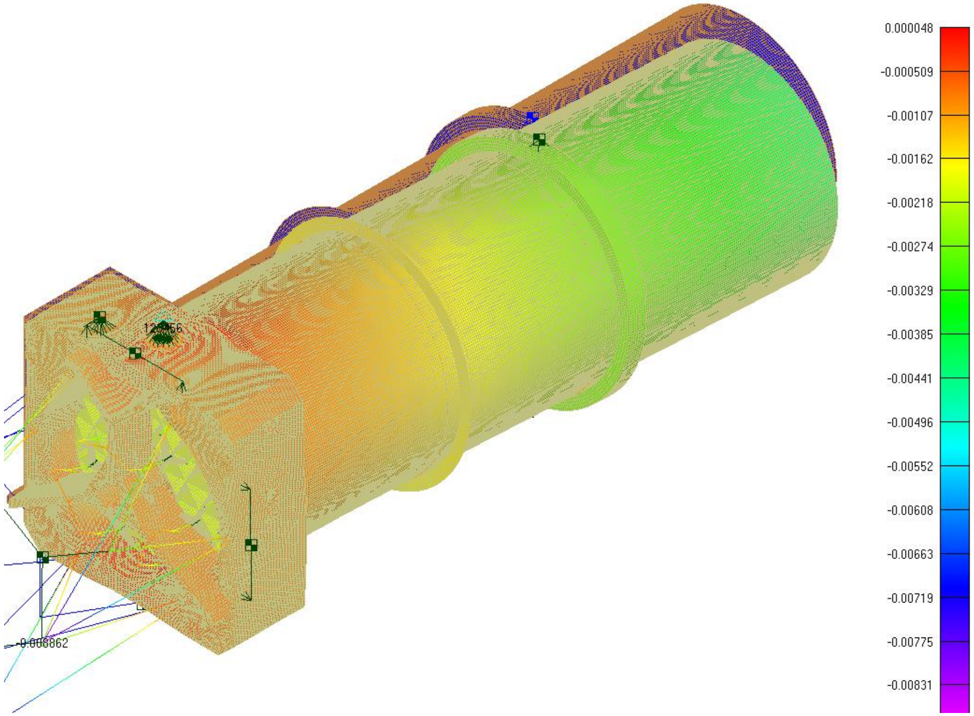


SFE when pointing vertically; defocus removed; 632.8nm waves

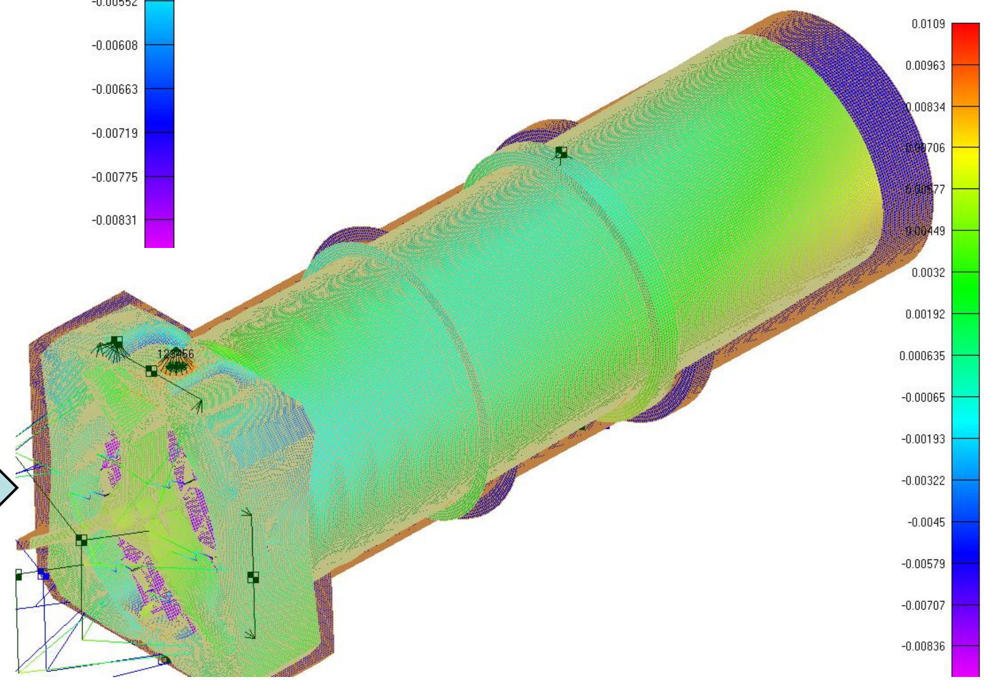
- All other pointing angles will have surface figure error (SFE) that is a weighted average of these two cases
- Asymmetry in the Vertical pointing case is caused by tangent bar asymmetry
- The SFE over the mirror’s surface is RMSed to determine the RMS SFE

Telescope Deflection

Deflection of the Telescope:



Deformation of the telescope due to a 1g loading in the –y direction, scaled 2000 times.



Deformation of the telescope due to the Worst Case thermal loading, scaled 500 times.