

Measuring and Mitigating Roman Space Telescope Reaction Wheel Imbalance Forces and Torques

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Parker Lin – KBR

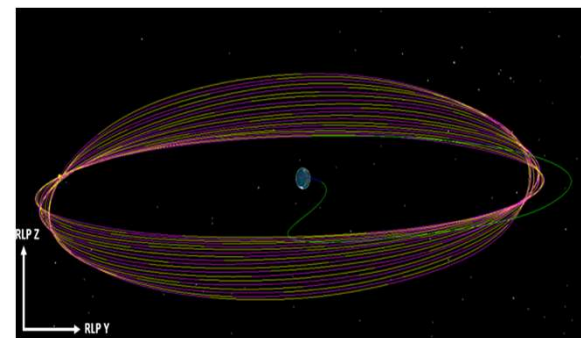
Larry Sokolsky – Aerodyne

Robert Champion – Aerodyne

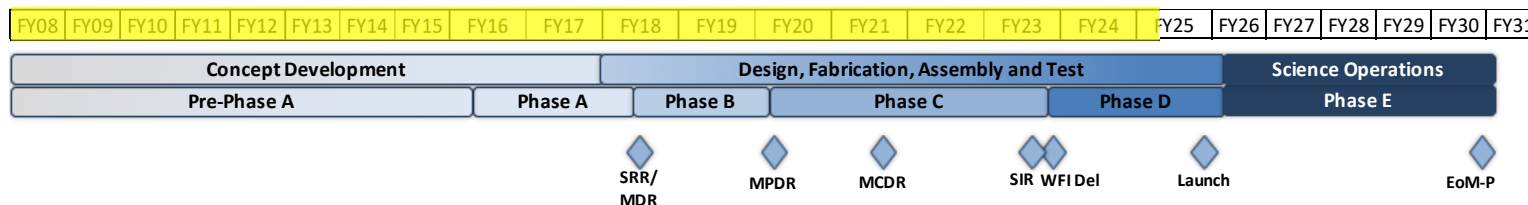
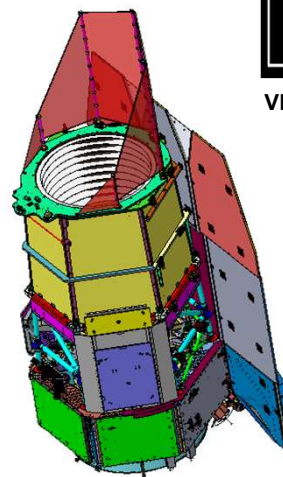
Kuo-Chia (Alice) Liu – NASA

Roman Mission Overview

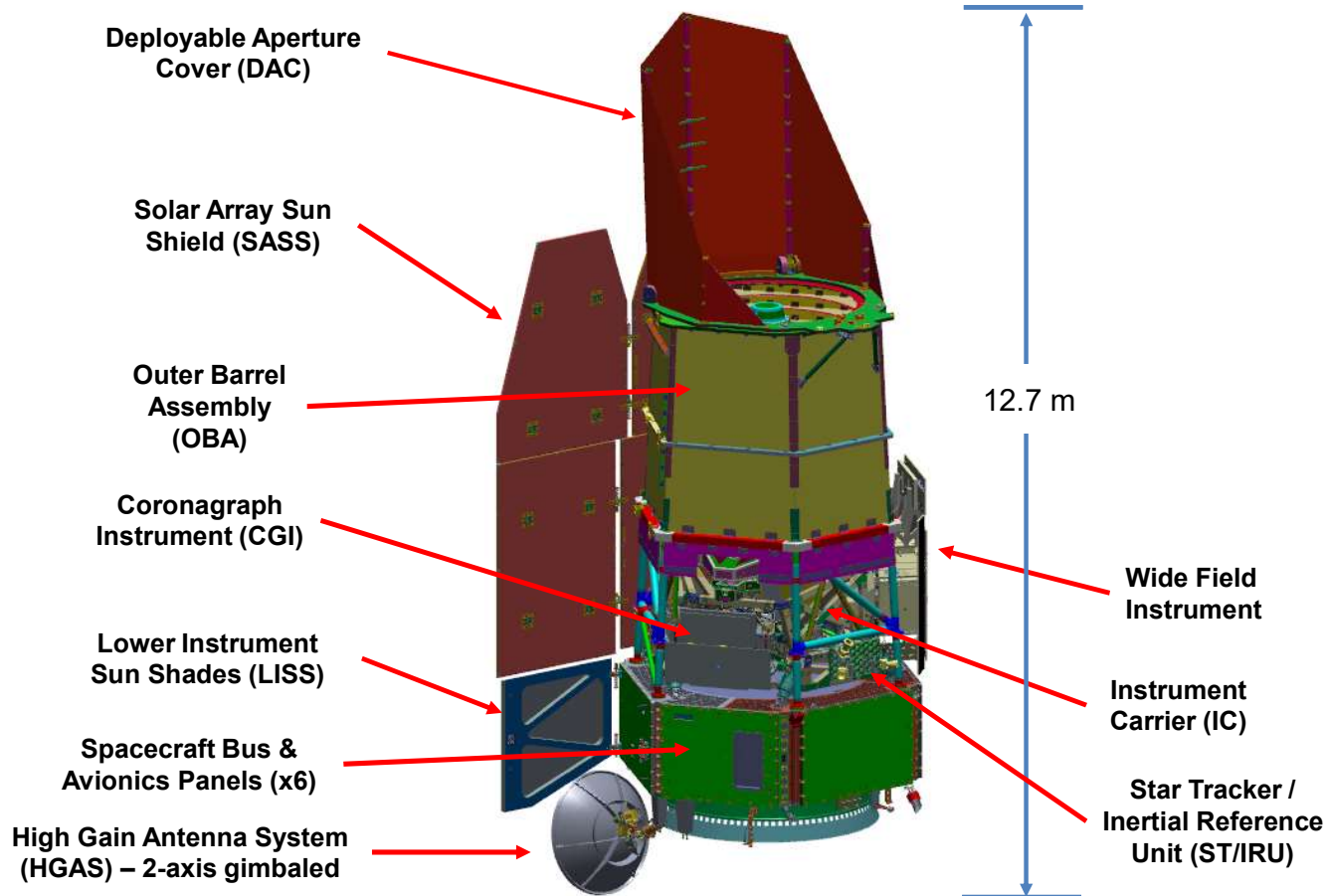
- **RST:** Nancy Grace Roman Space Telescope (Class A)
- **Mission:** Wide-Field Infrared Survey
- **Objectives:**
 - Determine the nature of the dark energy that is driving the current accelerating expansion of the universe
 - Perform statistical census of planetary systems through microlensing survey
 - Survey the NIR sky
 - Provide the community with a wide field telescope for pointed observations
 - Fly a technology demonstration of a high-contrast coronagraph instrument
- **Mission Duration:** 5 years science
- **Orbit:** Quasi-Halo Orbit about Sun-Earth L2
- **Launch Vehicle:** Falcon Heavy
- **Launch Site:** Eastern Range
- **Mission Budget:** \$3.3 Billion through Phase E
- **Mass:** 10,750 kg (NTE)
- **LRD:** October 2026



VIEW FROM EARTH TO L2



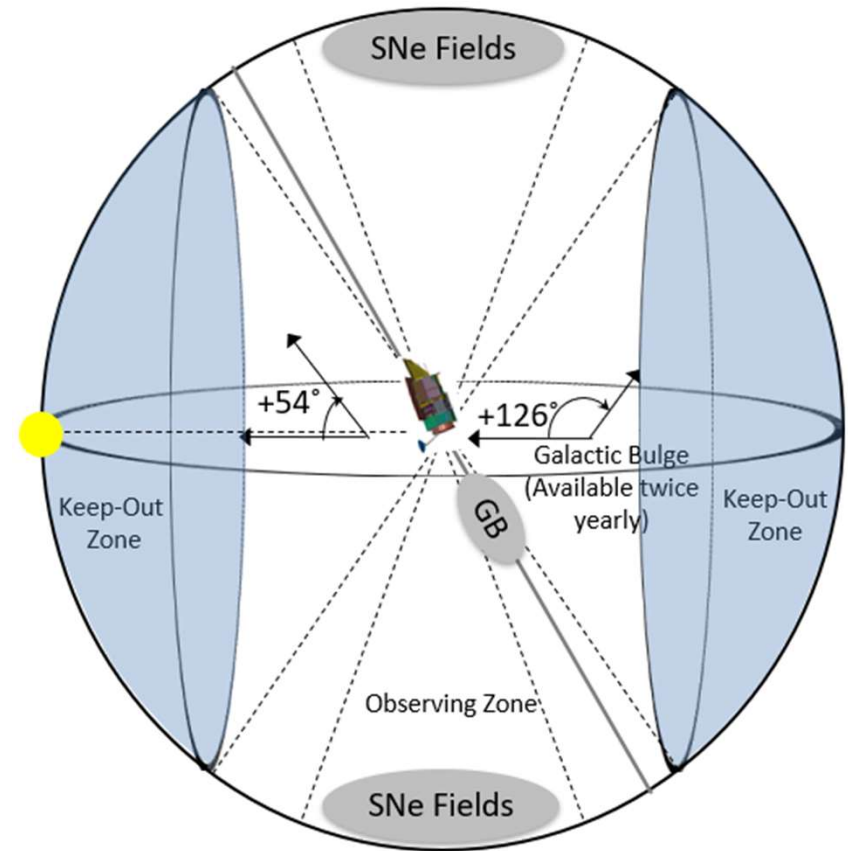
Observatory Overview



Observatory:

- Payload:
 - Optical Telescope Assembly
 - Instrument Carrier
 - Wide Field Instrument
 - Coronagraph Instrument
- Spacecraft
 - SC Bus
 - Outer Barrel Assembly
 - Solar Array Sun Shield
 - Deployable Aperture Cover
 - Lower Instrument Sun Shades
 - High Gain Antenna System
 - ST/IRU

- **The Roman Mission consists of a five-part observing program:**
 - **High Latitude Wide Area Survey:** Spectroscopic & Imaging sky survey for Baryon Acoustic Oscillation (BAO) / Redshift space distortion (RSD) & Weak Lensing/Galaxy Clustering
 - Mapping $>1,700 \text{ deg}^2$, observations of $\sim 140 \text{ sec}$ (imaging) or $\sim 300 \text{ sec}$ (spectroscopy)
 - **High Latitude Time Domain Survey:** Multiple visits to fields at high ecliptic latitudes to discover and track Supernova
 - 30 hours of imaging and spectroscopic observations every 5 days
 - **Galactic Bulge Time Domain Survey:** Repeated visits to fields near the Galactic bulge to monitor planetary microlensing events
 - Repeated viewing of 7 fields every 15 minutes for 60 days
 - **Exoplanet Coronagraphy:** Targeted observations of nearby stars for technology demonstration of high-contrast imaging and spectroscopy
 - **General Observer:** Allocated time for proposers to observe targets anywhere within the field of regard
 - All portions of the sky in the FOR are visible during otherwise-unallocated time

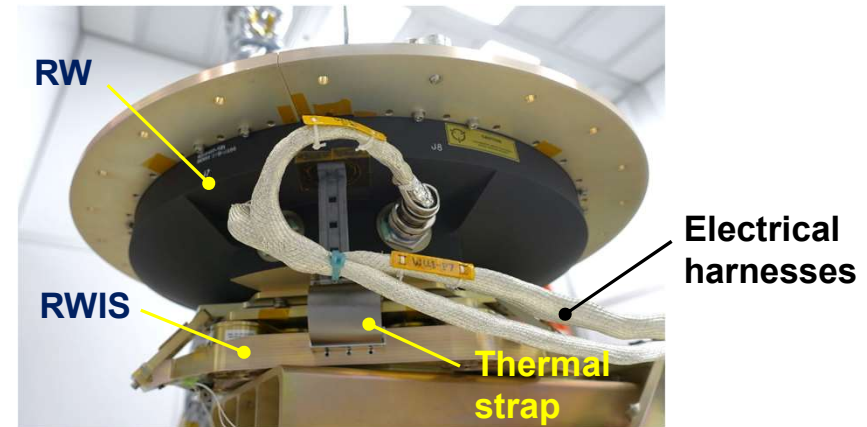
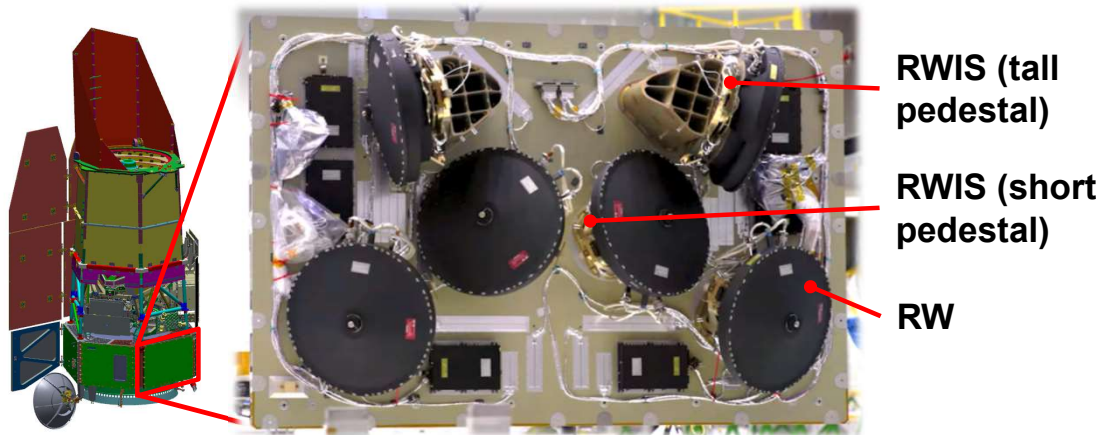


Roman Field of Regard (FOR)

Roman Space Telescope Architecture w/ RW/RWIS Assembly

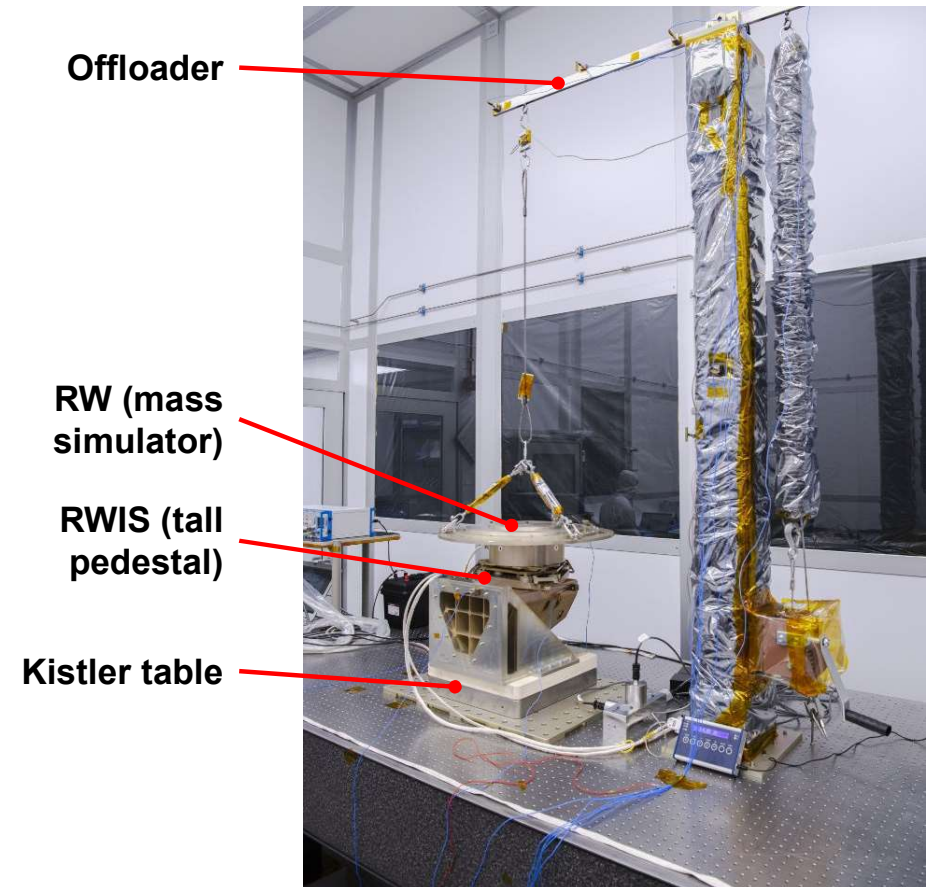


- ❑ **RST has 6 Honeywell HR18-250 reaction wheels (RW)**
 - Speeds up to ~ 2400 RPM (40 Hz)
 - Source of vibration/jitter
- ❑ **Reaction Wheel Isolation System (RWIS) developed for RST by Moog CSA**
 - Attenuates vibration transmitted to the spacecraft bus and into the optical payload
 - Primary isolation modes at ~ 3 Hz
 - Two variants (tall & short pedestal) to orient the RWs at the correct angle on the spacecraft bus panel
- ❑ **Some mechanical shorts cross the isolation boundary**
 - Thermal straps and electrical harnesses
 - Bypass RWIS, adversely impact observatory jitter
- ❑ **RW and RWIS vendors provide test-correlated models**
 - Models do not include thermal straps or harnesses
- ❑ **Transmissibility testing:**
 - Assembly-level test
 - Characterize mechanical shorts
 - Validate RW/RWIS exported disturbance for observatory-level jitter prediction

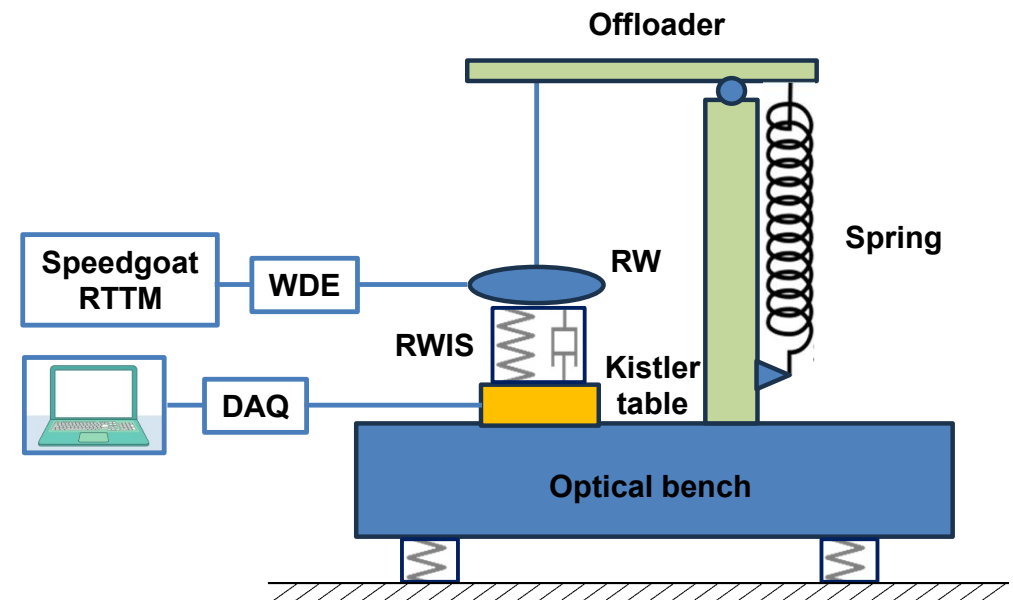


RW/RWIS Transmissibility Test Setup – 1/2

- ❑ **Low RWIS stiffness requires a gravity offload system**
 - Offloader designed with a 0.3 Hz primary mode for frequency separation from 3 Hz isolator modes
 - Spring offloader reduces added inertia compared to counterbalance
 - Lever reduces required spring travel
 - Flexure pivot reduces friction
- ❑ **Set up on optical bench**
 - Pneumatic vibration isolators reduce environmental disturbance
- ❑ **Exported disturbance measured with Kistler microvibration force plate (Kistler table)**
 - Captures 6-axis forces and moments at base of isolator
- ❑ **Additional vibration data captured using 3-axis accelerometers**
- ❑ **RW speed controlled and monitored by Speedgoat real-time target machine**
 - Emulates flight electronics interface

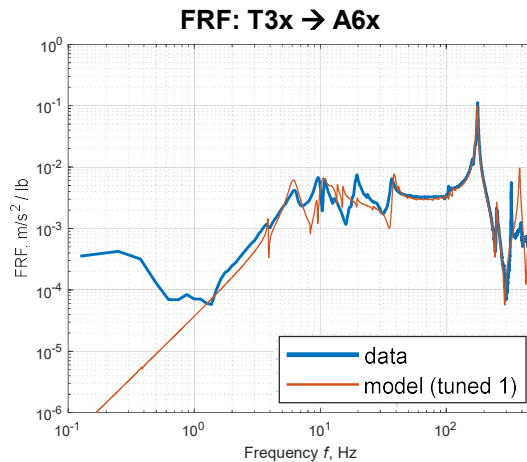
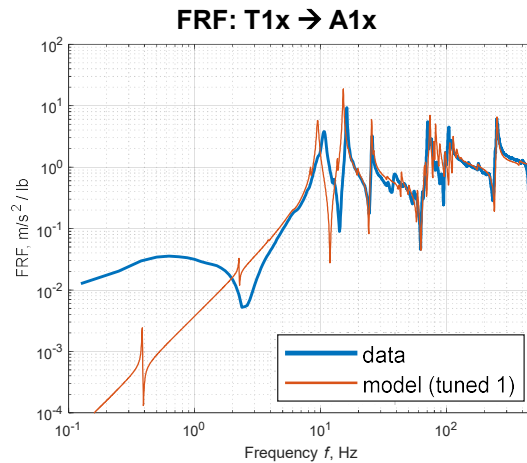
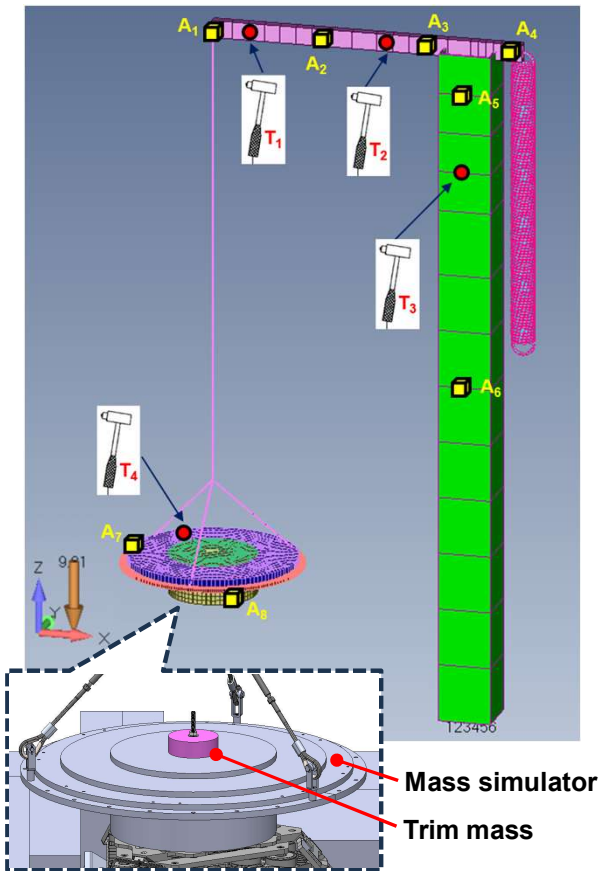


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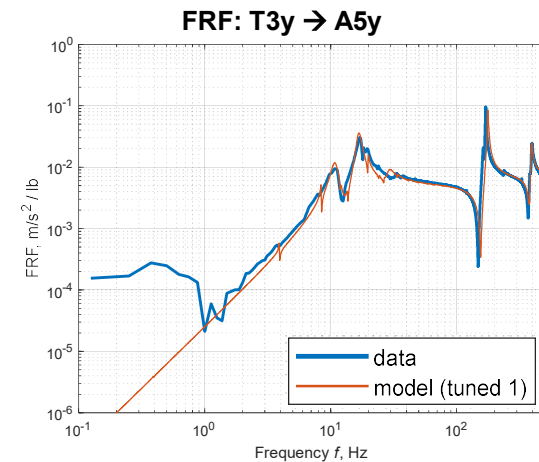


GSE Characterization and Correlation

A_1 – A_8 : Accelerometer locations
 T_1 – T_4 : Tap locations

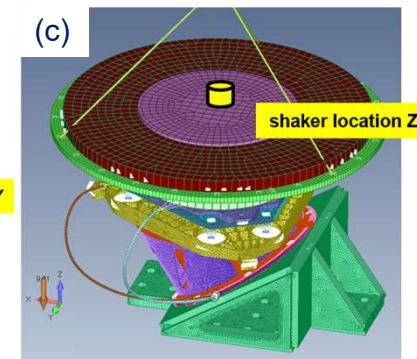
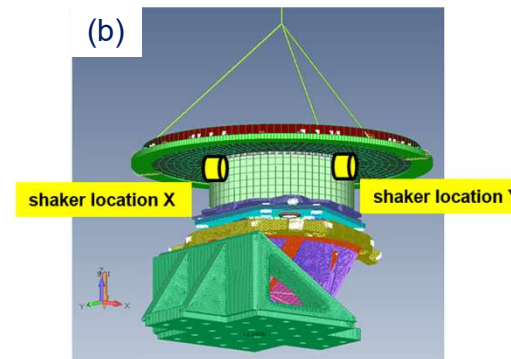
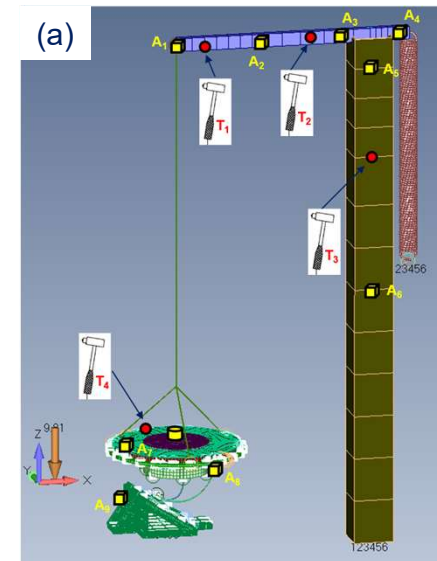


- Offloader dynamics characterized through tap testing
- Ground support equipment (GSE) instrumented with accelerometers
 - Offloader lever and tower
 - RW mass simulator
 - RWIS brackets
- Frequency Response Functions (FRFs) used for correlation of GSE model.
- Predicted responses (red) from the correlated model match measured FRFs of the tower & lever dynamics (blue)



Tap & Transmissibility Tests

- **Harness & thermal strap characterization**
 - RW mass simulator, EDU RWIS
 - Harnesses, short pedestal bracket, no RWIS (a)
 - Short & tall RWIS/pedestal, no harnesses (b)
 - Short & tall RWIS/pedestal, harnesses/thermal straps (c)
 - Accelerometer & instrumented hammer data captured
- **Transmissibility / exported disturbance tests**
 - Flight RW, flight RWIS
 - Flight thermal straps
 - Flight-like harnesses
 - Wheel driven from 0 to 2600 RPM
 - Constant torque at ~60 RPM/s
 - 30 RPM steps, 40 s per step
 - Exported disturbance data captured with Kistler table
- **Model correlation**
 - Data used to tune thermal strap and harness properties
 - Further tuning of GSE models
 - Vendor-provided RW and RWIS models not modified
 - Correlated Honeywell disturbance model used for exported disturbance predictions

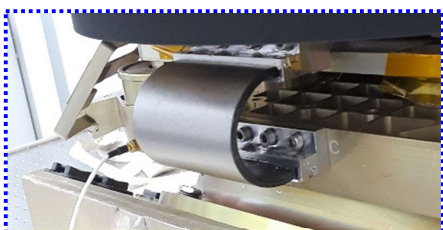


Thermal Strap Design Optimization

Baseline thermal strap

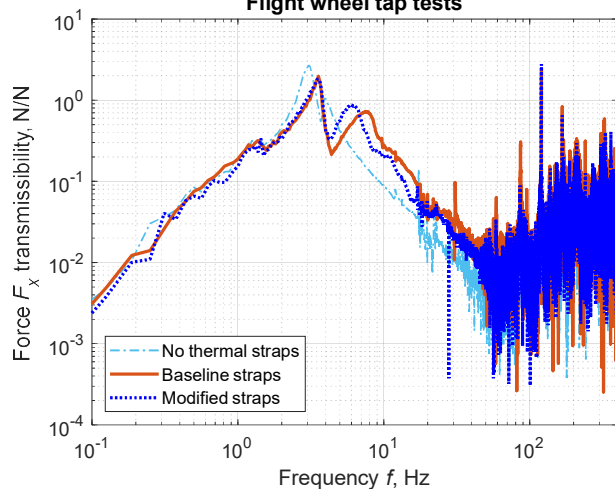


Modified thermal strap:
30% layers removed

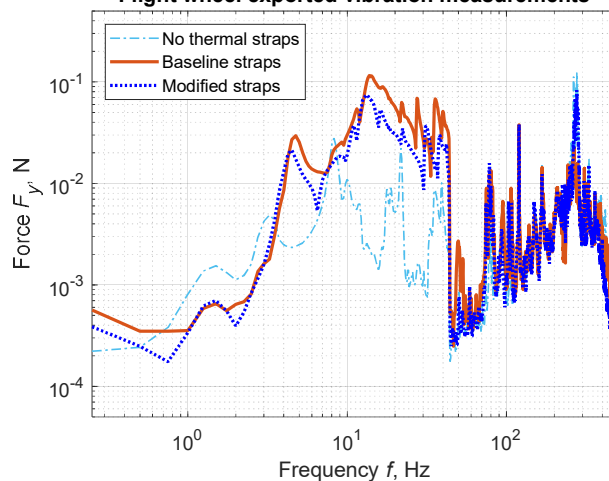


- ❑ **Baseline thermal straps caused significant isolation performance degradation**
 - Resulted in exceedance of observatory level jitter requirements
- ❑ **Thermal strap modification tested**
 - Thermal sensitivity analysis determined 30% reduction of layers meets thermal requirements
 - Tap and exported disturbance data showed improved response due to decreased parasitic stiffness
- ❑ **Correlated model shows good match to test data in transmissibility and exported disturbance**
- ❑ **Similar correlation performed for harness**
 - Optimized compliance / routing / tiedown points
 - Much smaller effect than thermal straps

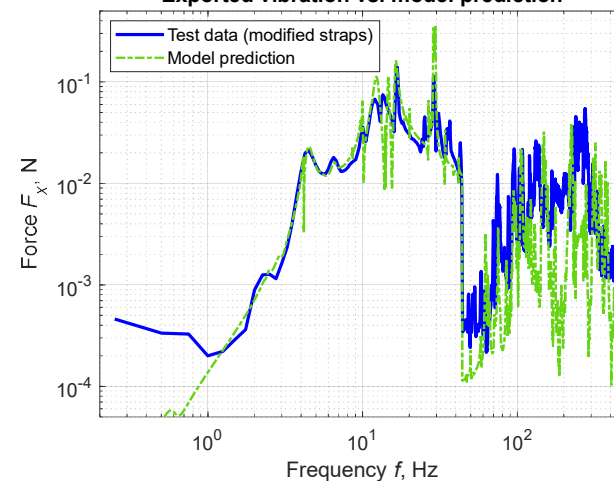
Flight wheel tap tests



Flight wheel exported vibration measurements



Exported vibration vs. model prediction



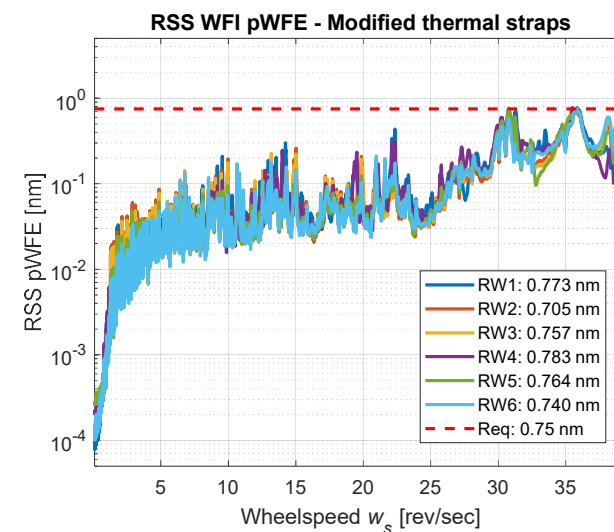
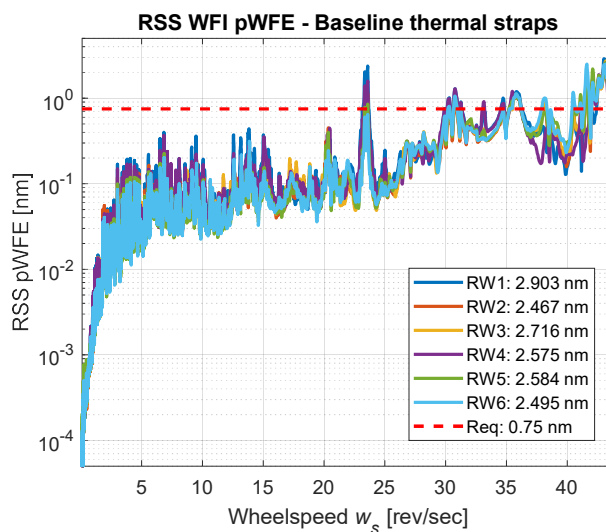
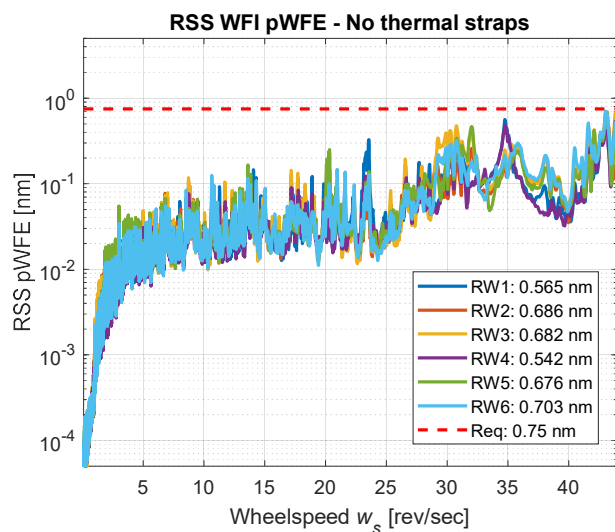
RWA-Induced Observatory Jitter Performance Comparison



- ❑ **Observatory jitter / wavefront error (WFE) meet system level requirements with no thermal straps**
 - Early analysis assumed minimal RWIS performance degradation from thermal straps
- ❑ **Addition of correlated thermal strap model revealed multiple exceedances in various wheel speed ranges**
 - Thermal strap parasitic stiffness considerably degraded RWIS performance
 - WFE requirements not met
- ❑ **Modifications to thermal straps significantly improved observatory performance**
 - Remaining slight jitter exceedance accommodated within the system-level error budget
- ❑ **Jitter requirement met through design iteration and optimization**

RST Model Uncertainty Factor

Frequency range (Hz)	MUF
0–50	3
50–100	3–8
100–320	8
320–350	8–10
350–400	10



Conclusion



- ❑ **Through a carefully designed experiment which enabled:**
 - Running gravity-offloaded flight reaction wheels and isolators
 - Testing/correlating the offloader system
 - Recovering forces and moments with a precision dynamometer
- ❑ **Observed and quantified effects of parasitic loads (thermal straps and harnesses) which acted to partially ground out the isolator**
 - Correlated system-level models captured such unfavorable effects
 - Demonstrated that these parasitic loads were causing the system to exceed its jitter requirements
- ❑ **Test lessons learned applied to modifying the design of the parasitic loads to reduce their impact through optimizing:**
 - The number of thermally conductive layers in the thermal straps
 - Harness routing, tiedown points, and cladding stiffness
- ❑ **After completing the optimization process, system-level jitter requirements are once again met, even with a conservative MUF**