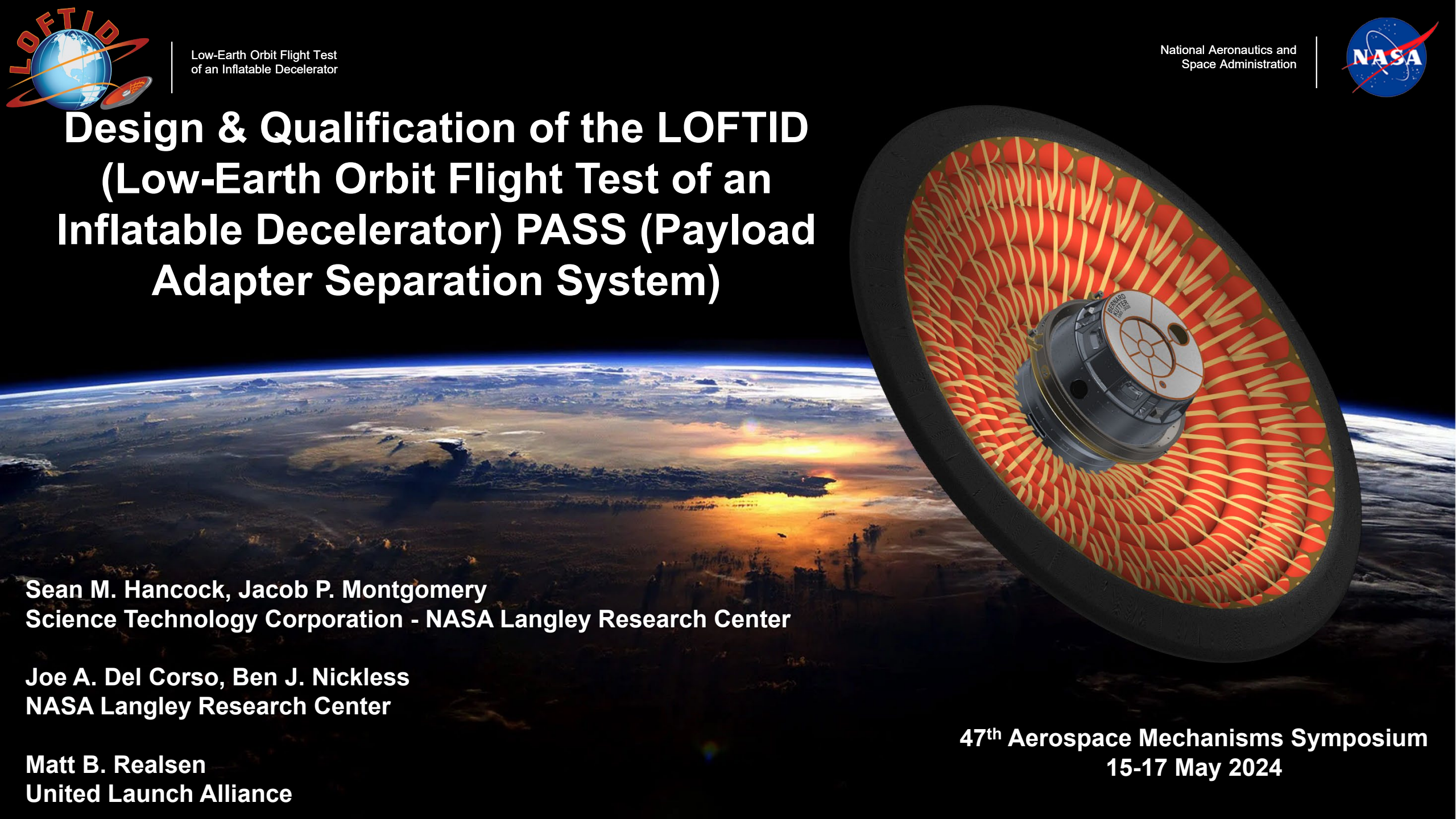

Design & Qualification of the LOFTID (Low-Earth Orbit Flight Test of an Inflatable Decelerator) PASS (Payload Adapter Separation System)

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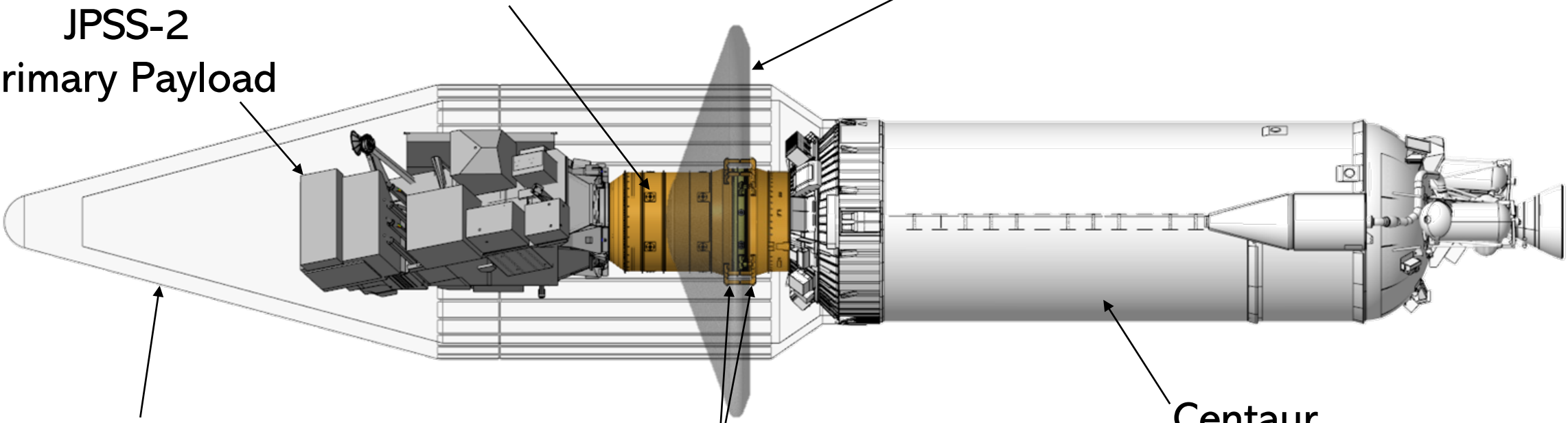
47th Aerospace Mechanisms Symposium
15-17 May 2024

Introduction

- November 10, 2022, LOFTID successfully demonstrated HIAD technology in an orbital test flight
- Demonstrated launch of 2 independent, similarly sized payloads
- Enabled by mission unique Payload Adapter Separation System

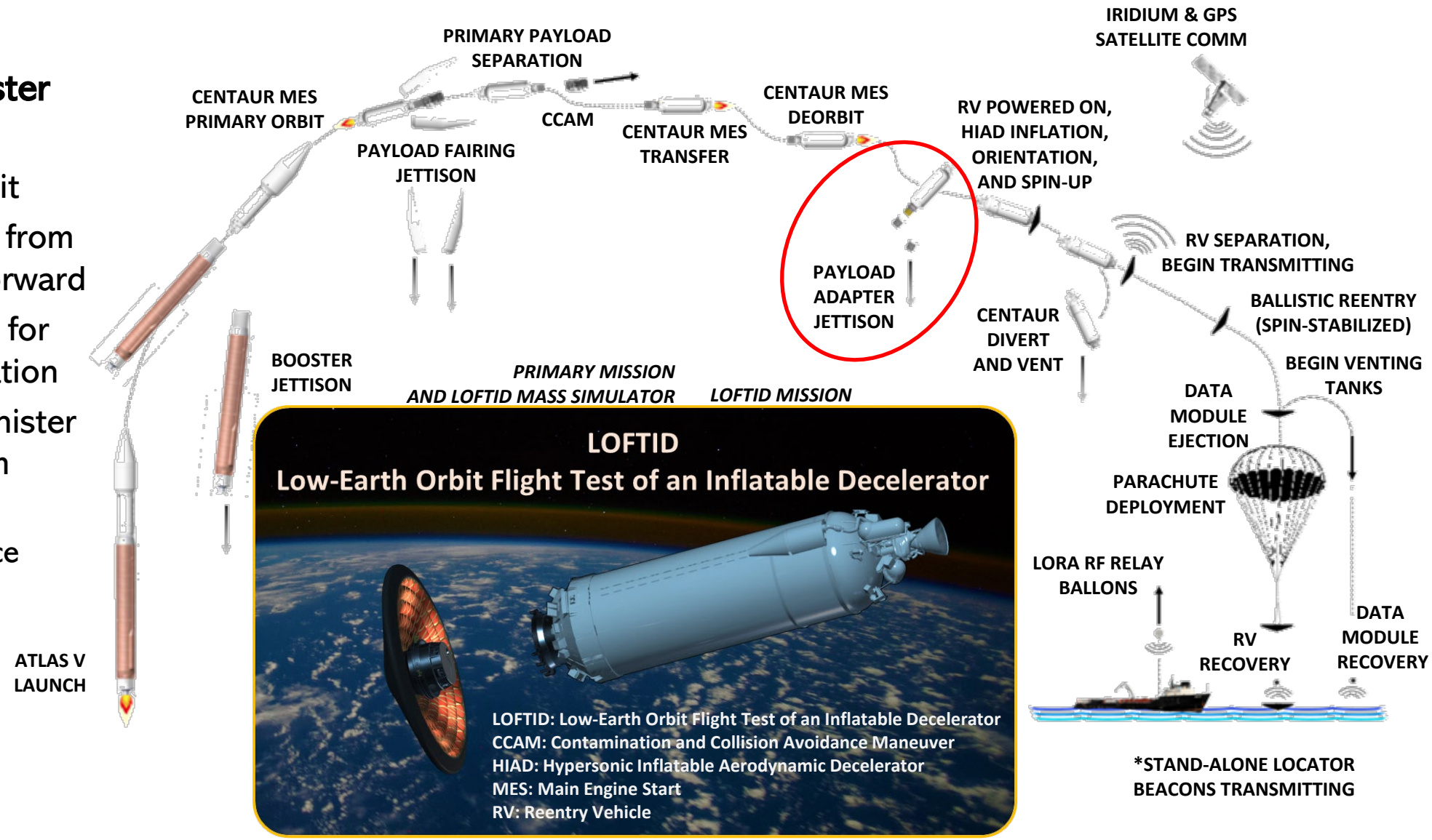
Image credit: ULA

Launch Configuration



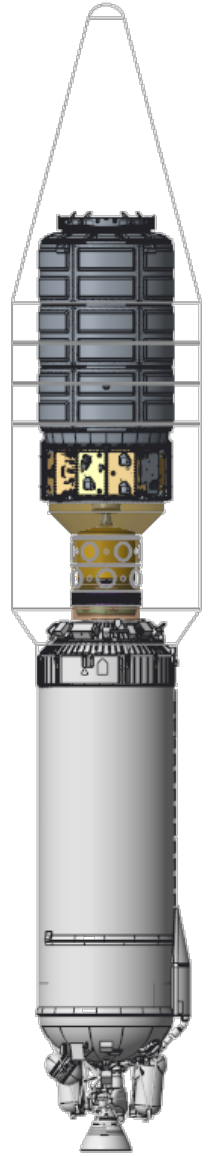
Concept of Operations

- **Payload Adapter Canister Jettison**
  - After Centaur Deorbit
  - Centaur Reorienting from ME forward to RV forward
  - Accelerations nulled for PLA Canister Separation
  - Payload Adapter Canister jettisoned away from direction of travel
    - Collision Avoidance



Rideshare

- ULA approached NASA in 2017 with proposal to use a HIAD for LV booster engine recovery
  - LOFTID developed as orbital flight demonstration to prove the concept
- Early rideshare considerations included Cygnus resupply and Landsat 9



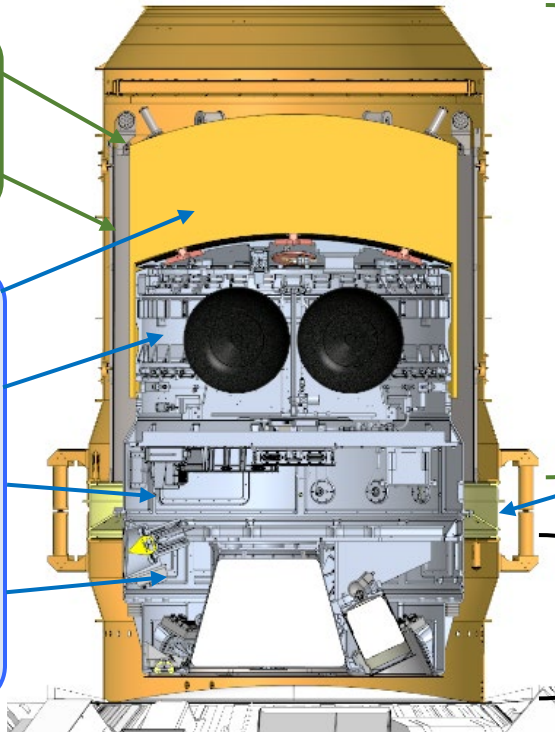
LOFTID Architecture

Payload Adapter Separation System (PASS)
Remains with PLA Canister at PLA Canister Jettison

- Halo & Springs
- Inner Shroud

Reentry Vehicle (RV)

- Hard-packed Aeroshell
- Fwd Segment & Inflation System with Tanks
- Mid Segment & Avionics Deck
- Aft Segment & Ejectable Data Recorder, Cameras, Beacons, & Parachute System

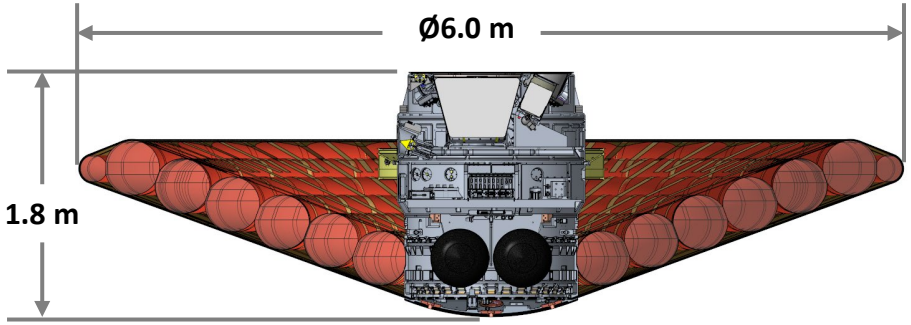


Payload Adapter (PLA) Canister

Interface Ring
Remains with RV at RV Separation

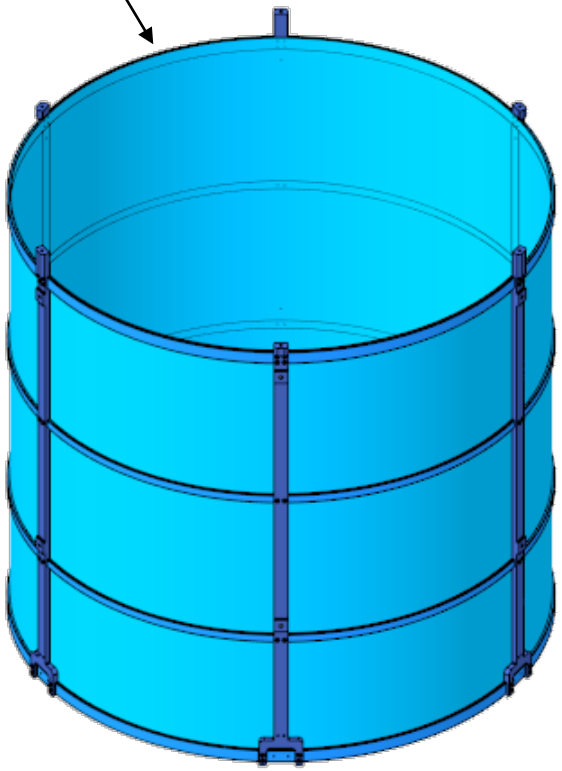
Payload Adapter
Remains with Centaur

Reentry Configuration
Mass: 1100 kg (2426 lbm)



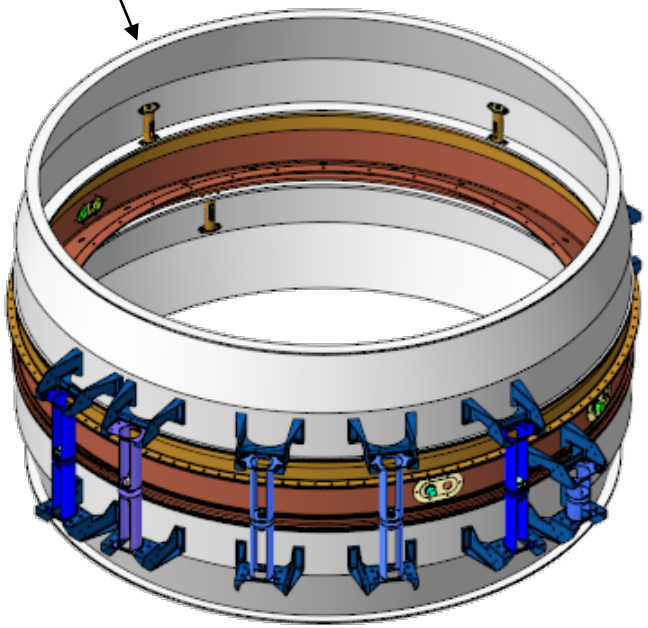
PASS Design

Inner Shroud



Halo

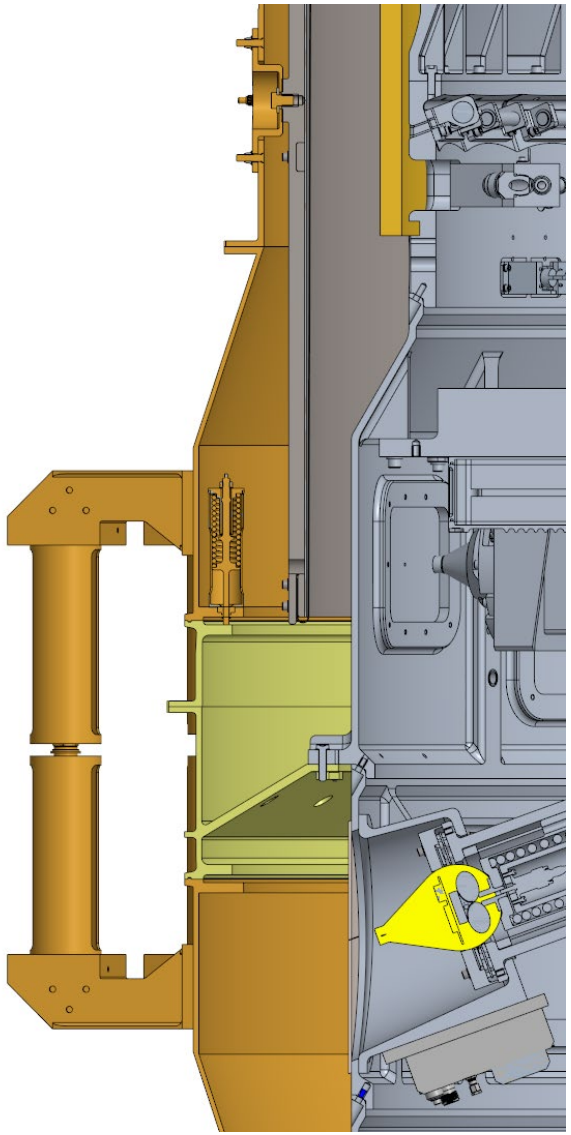
FWD 1666S
Payload Separation Ring

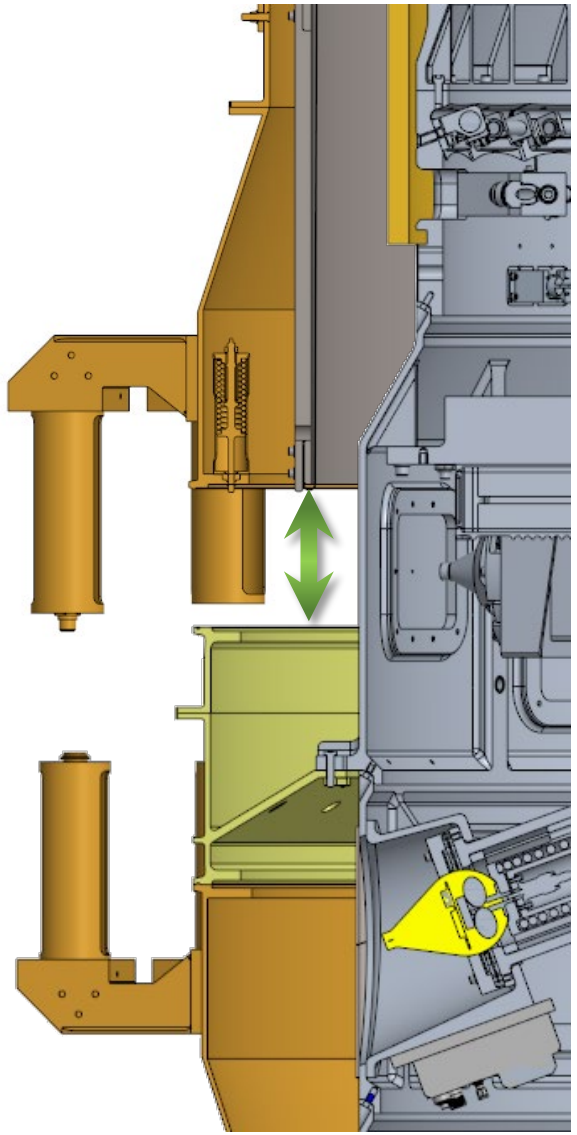


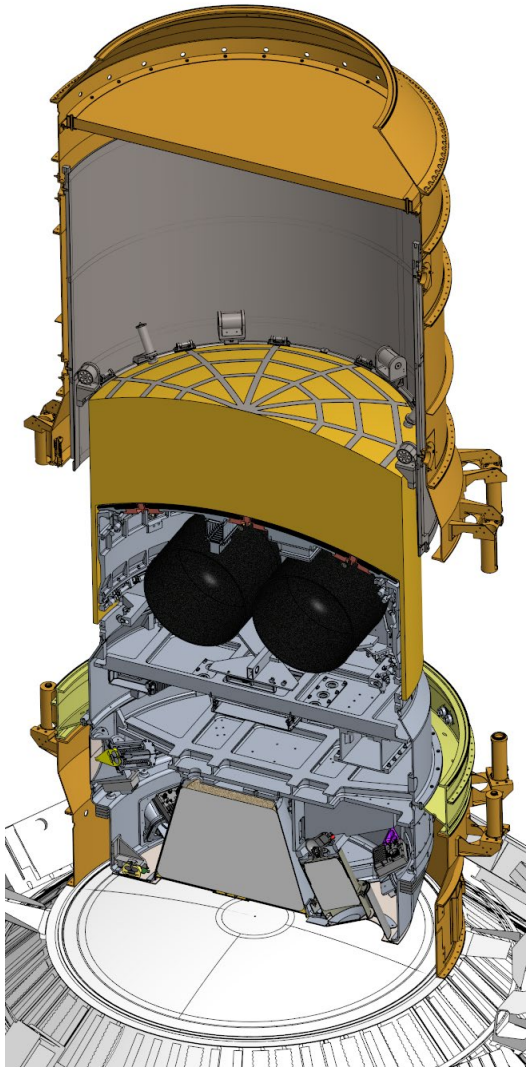
Long Stroke Separation System

1666S
Payload Separation Ring

PLA Canister Separation







Spring Component Qualification

Image credit: NASA

Constant Force Spring Characterization

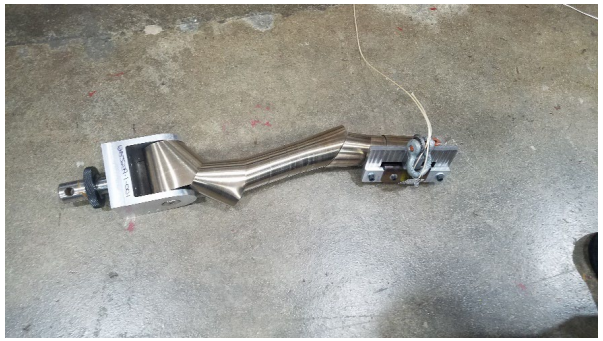


Image credit: NASA

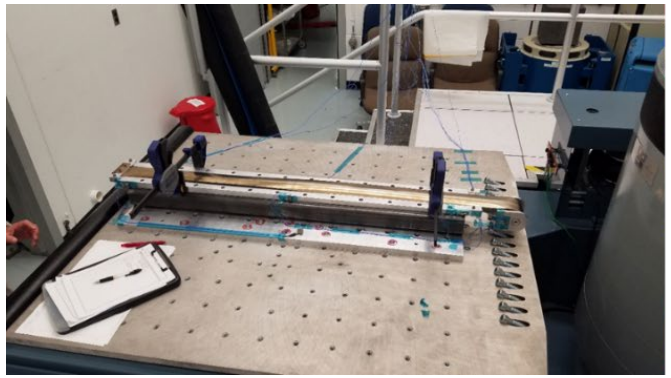


Image credit: NASA

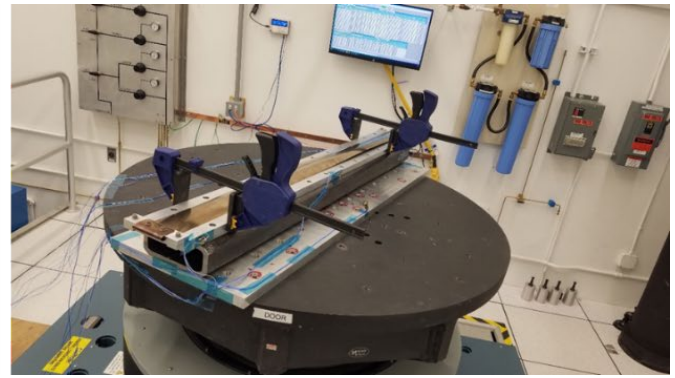


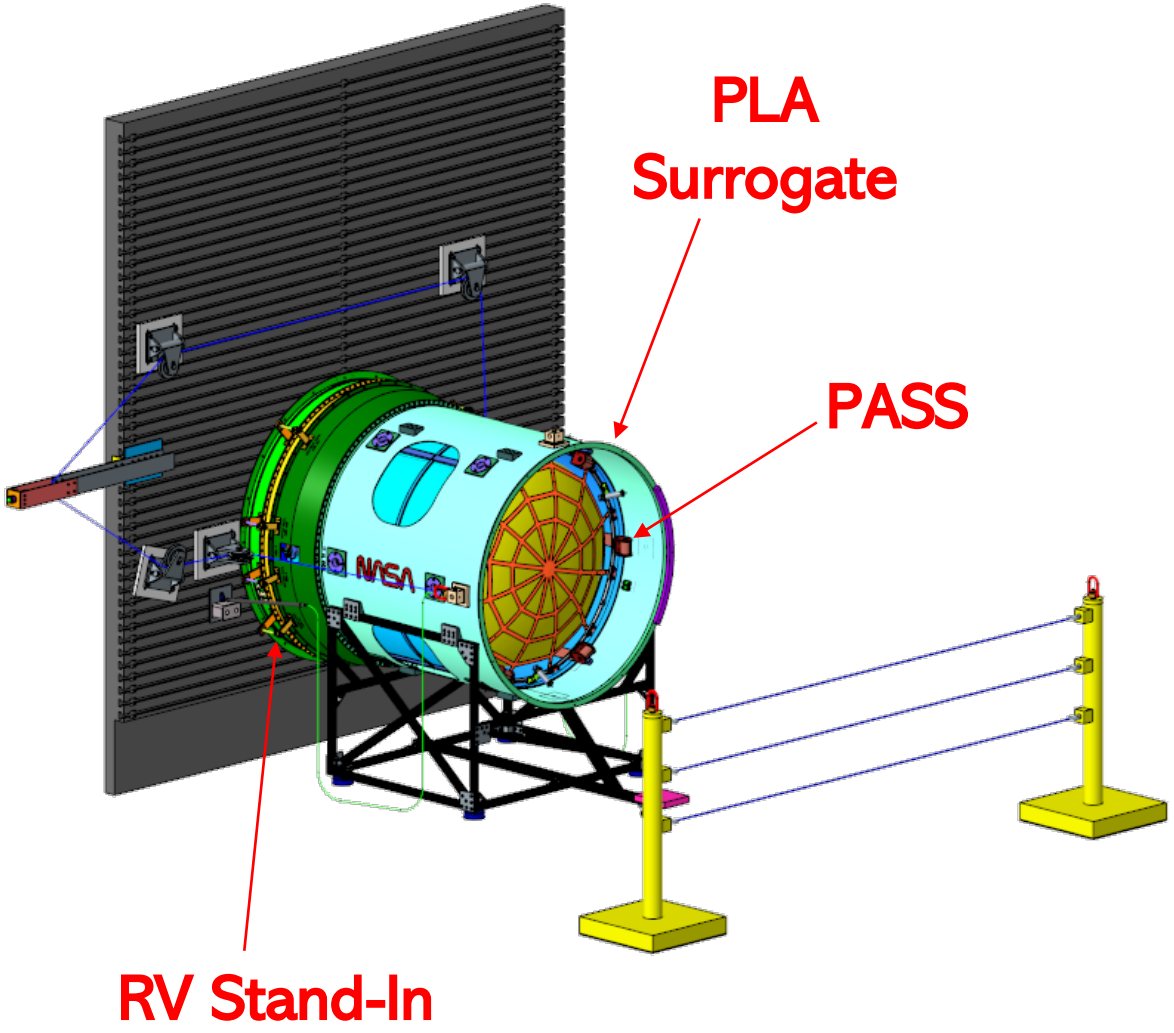
Image credit: NASA

Constant Force Spring Sine Vibe Testing

- Run-In / Life-Cycle Testing conducted at component level on springs
  - Run-In: Minimum of 15 Cycles
  - Life-Cycle: Total of 48 Cycles
- 12 Spring Sets characterized
- Matched set of 6 Springs selected

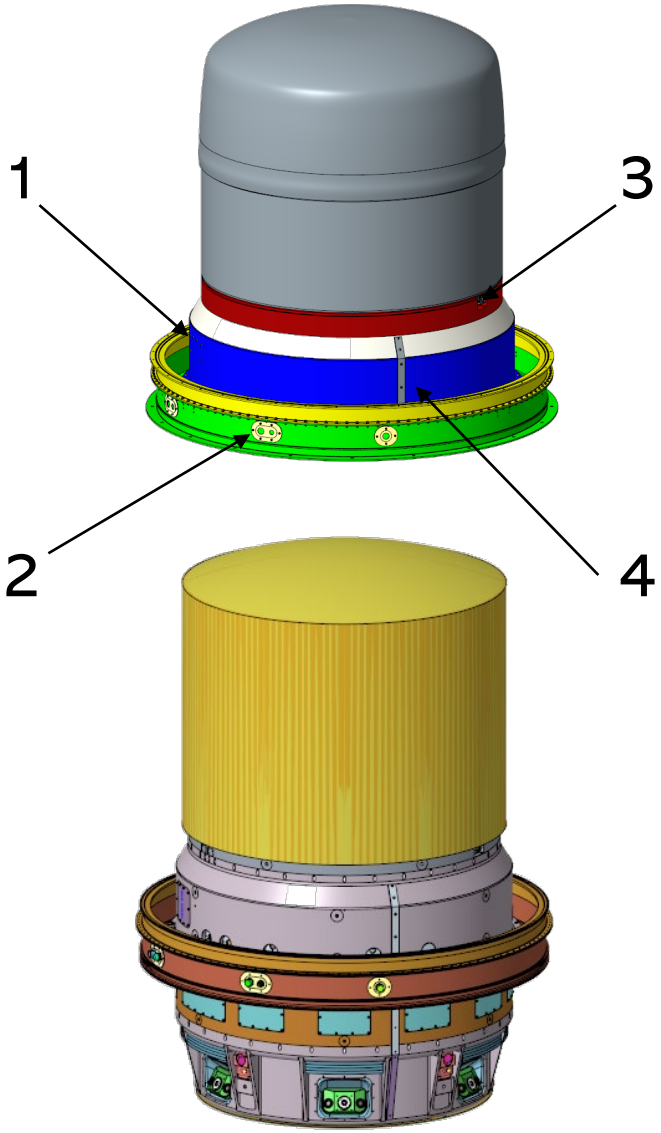
- **Destroyed first spring**
  - Lesson learned: Constrain spring against twisting (most likely failure mode)

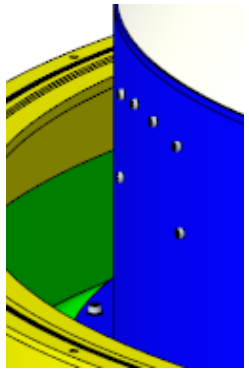
Mechanism Testing



Video credit: NASA

Reentry Vehicle Stand-In





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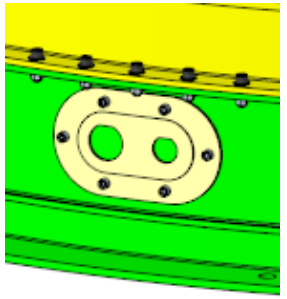

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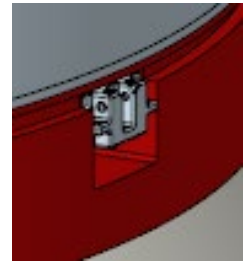

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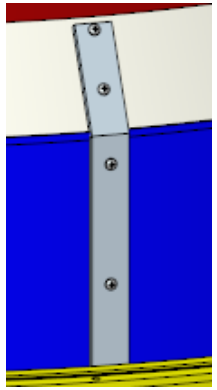

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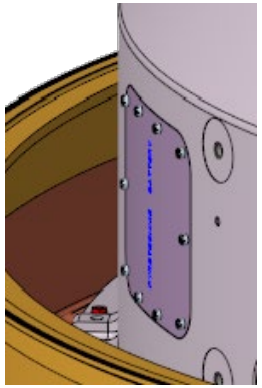
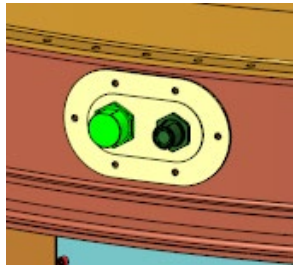
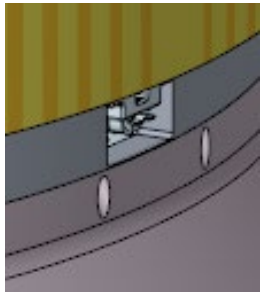
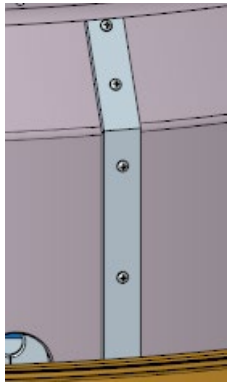
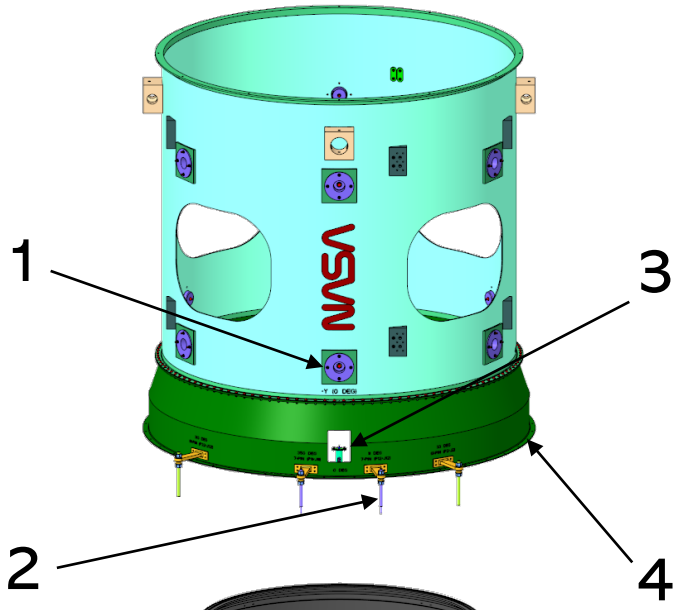


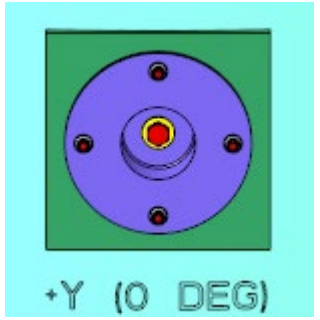






Payload Adapter Surrogate





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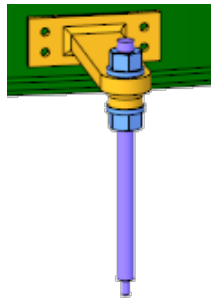

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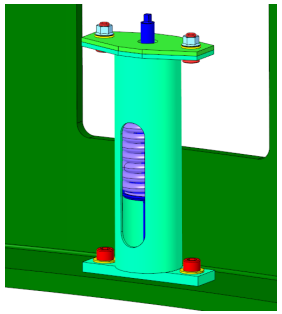

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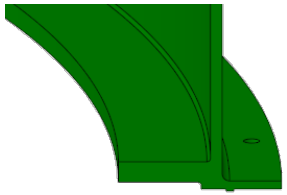

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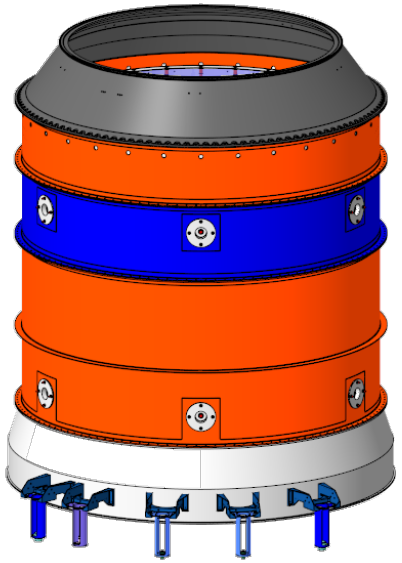
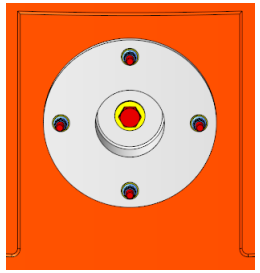
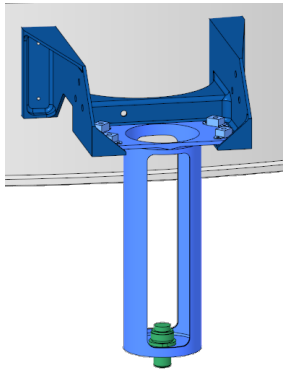
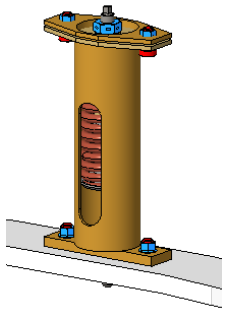
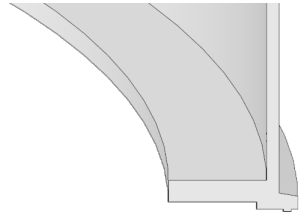




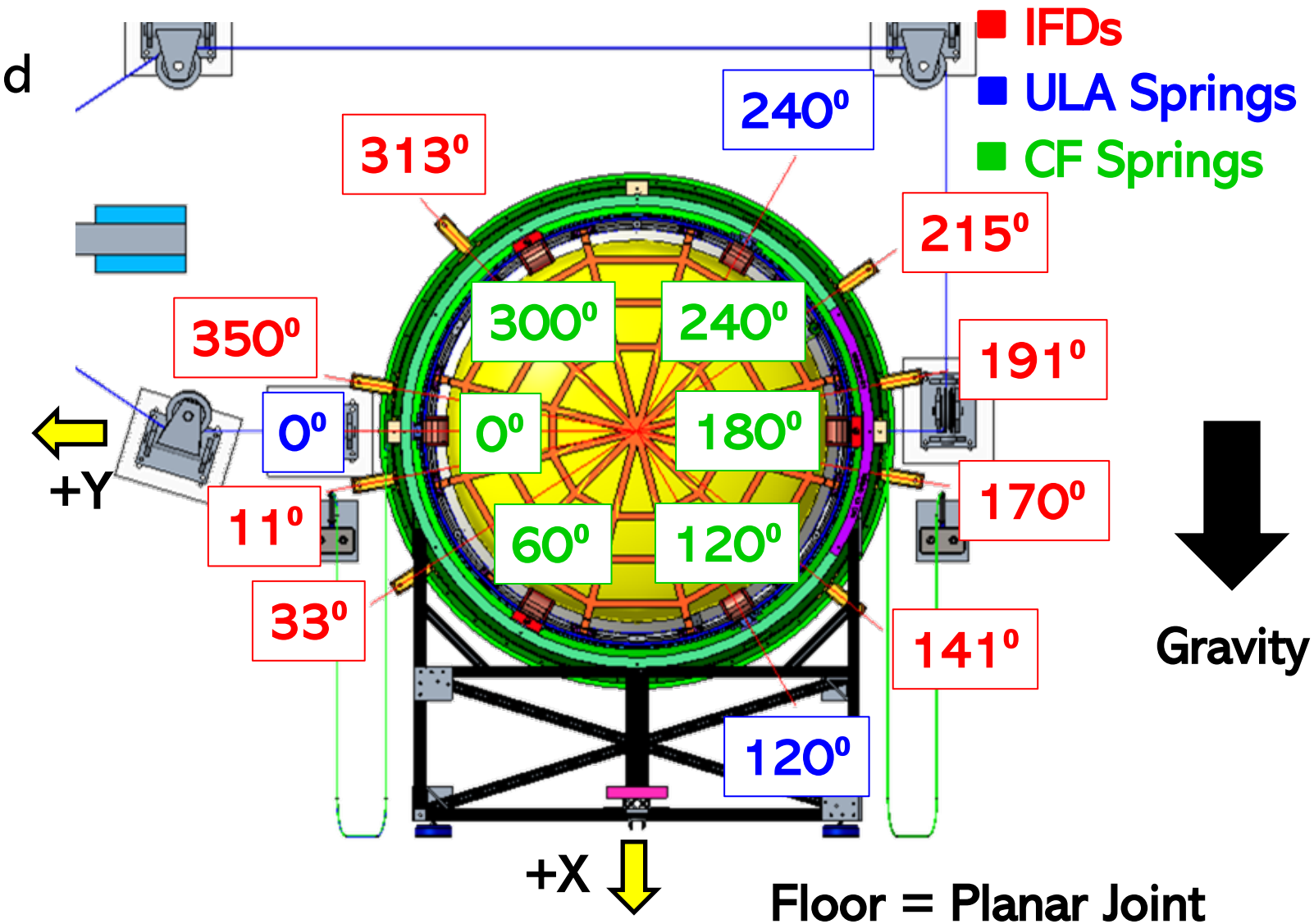




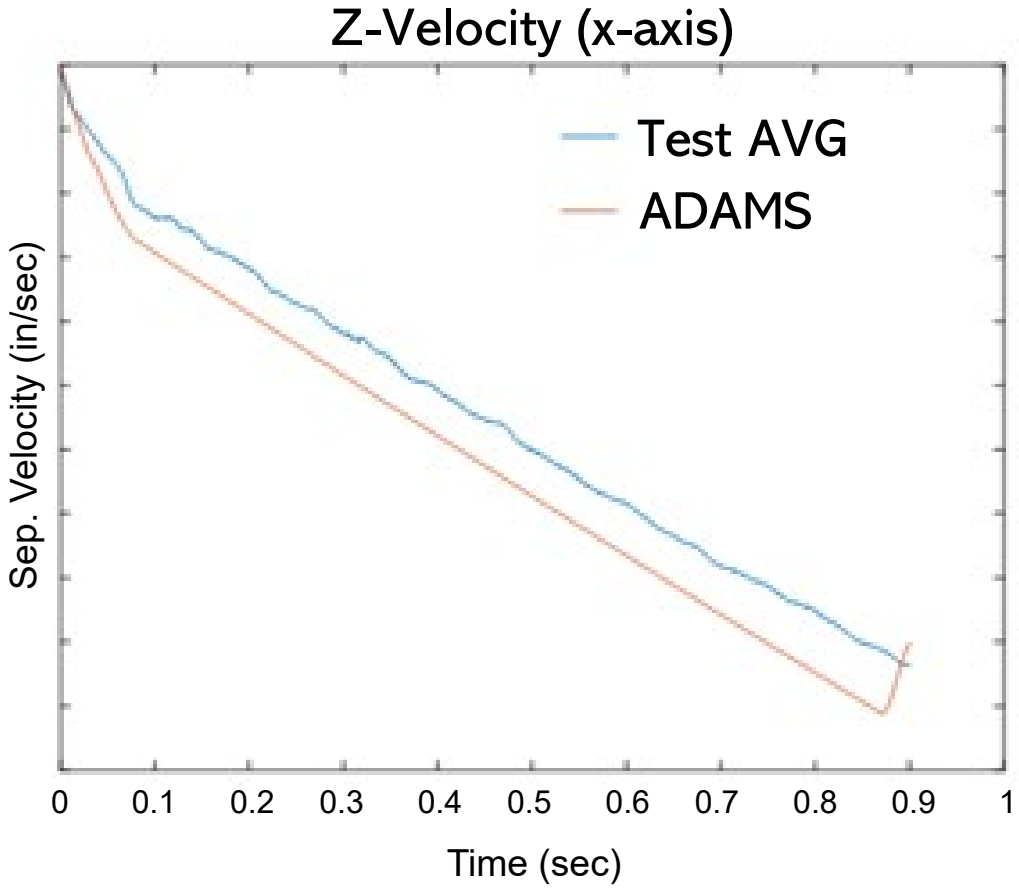


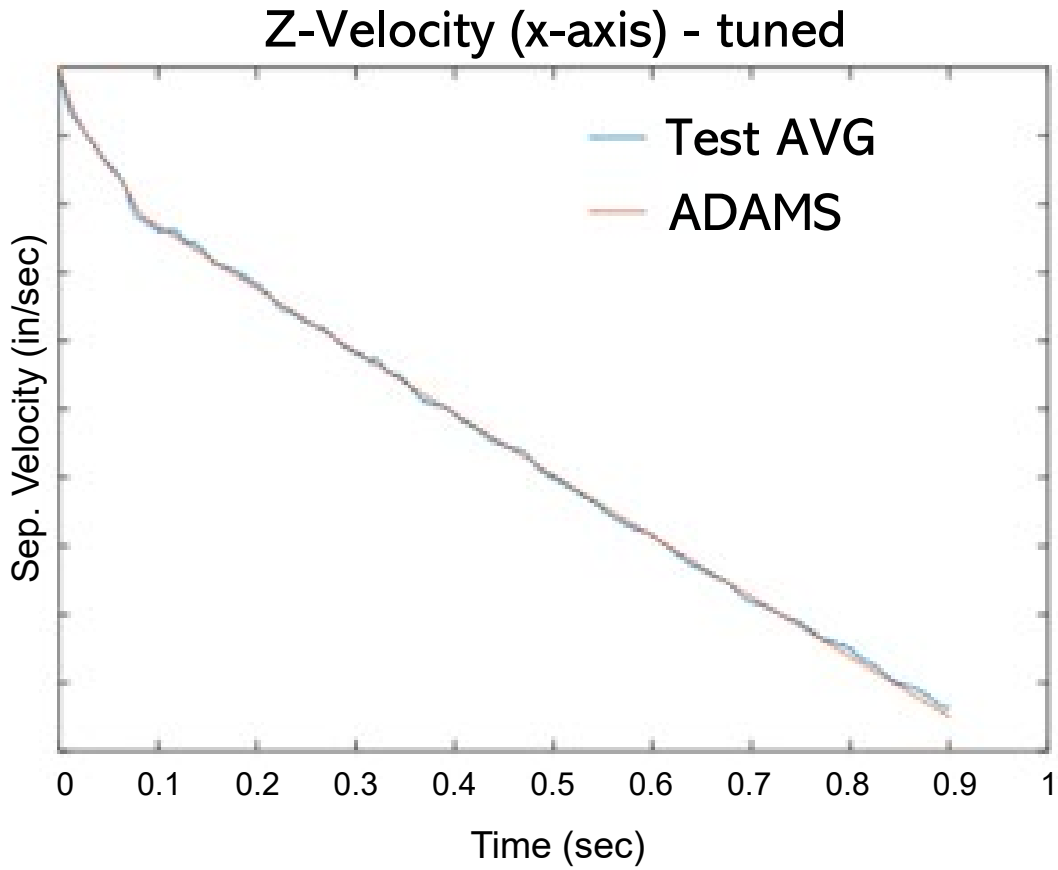
Dynamic Modeling

- ADAMS model developed and correlated to ground test results
  - Required to match +/- 10% test performance
- Modeled 3 separate bodies moving independently
  - RV& Centaur (lumped)
  - Canister/Inner Shroud
  - Halo
- All force inputs to model characterized prior to testing



Modeling Comparison

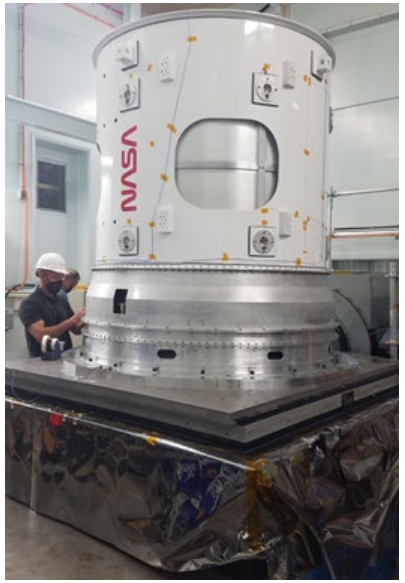




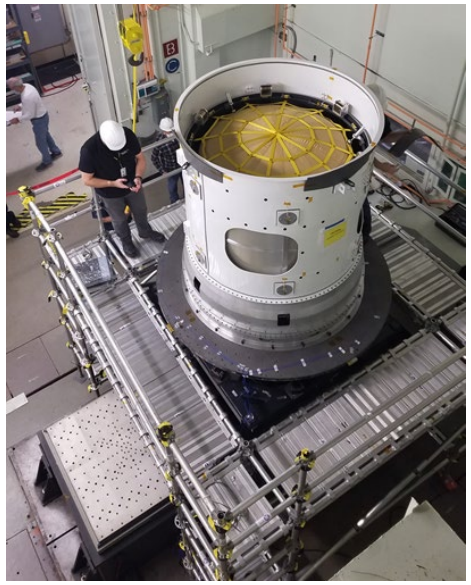
- ADAMS model correlated to ground testing w/in +/- 10% requirement
- Very good matching to translational motion
- Acceptable matching to rotational motion – very small rotations

Random Vibration Testing

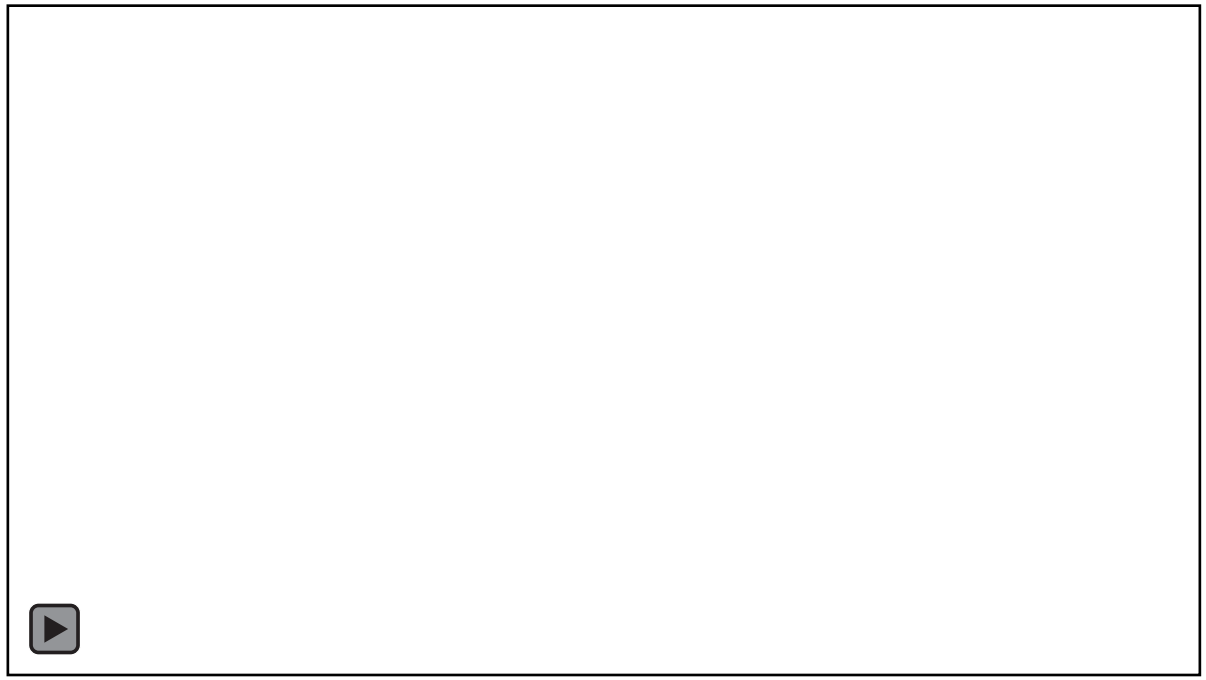
- **GSFC Vibration Test Facility 409 and 410**
- **Tested to Prototype Qualification Levels**
  - Random: Limit Level + 3dB, duration = 2 minutes per axis
- **Pass/Fail Criteria:**
  - Withstand qualification-level vibration tests without damage and pass the post-test inspection.
  - Successfully complete post-vibe PASS EDU Mechanism Performance Testing
  - No contact between PASS Halo and Inner Shroud
- **Requirements Verification**
  - Partial verification of PA.3010 PASS Load and Environments (V.PA.3010.T3)
  - Inform verification of ICD Requirement 3.1.1.1



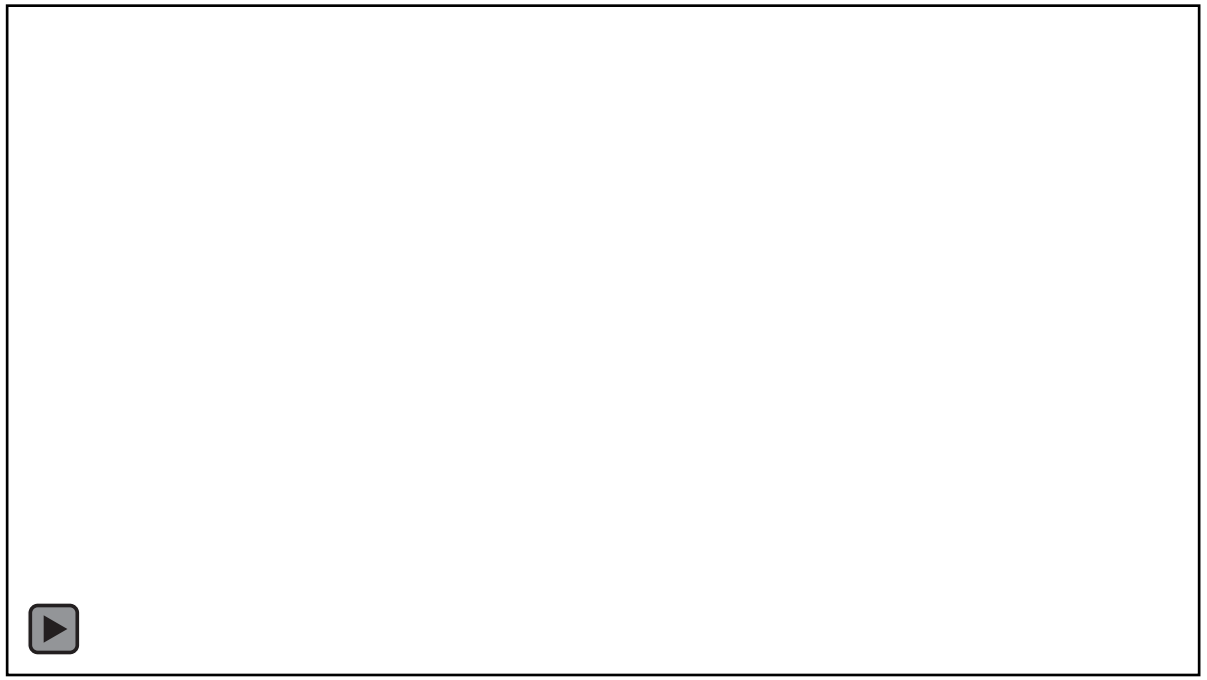
- **Issues with GSE RV Stand-In after x-axis tested necessitated return to LaRC for repairs**
- **Modified Launch Locks after 1st x-axis test due to Halo movement**
  - Modified Launch Locks do very good job of keeping Halo Centered
- **Lesson Learned: Bottom of area where Halo webbing overlaps caused light abrasion of restraint bag**
  - Kapton tape resolved issue



Summary



Video credit: ULA



Video credit: NASA

- **31 Successful Deployments – 24 EDU Ground Tests (including off-nominal), 6 Flight Unit Ground Tests, Flight**
- **Flawless Performance in Flight**
  - No noticeable tip-off
  - Separation velocity in kind with ground testing

Questions

Back-up

Qualification Test Matrix

Test	Recommended	LOFTID
Run-In	X	15 Cycles at Spring Level; Min 3 at Assy Level
Performance	Envelopes	Nominal Actuation
Random Vibration	Qual Level	Qual Level
Acoustic Vibration	Qual Level	Covered by Random Environments
Sine Vibration	Qual Level	Not Required
Thermal Cycle	X	Thermally Characterized Spring Sets
Life Cycle	X	48 Cycles at Spring Level; Min 5 at Assy Level
Static Loads	X	Analysis Only
Performance	Envelopes	Nominal, Envelopes, Off-Nominal