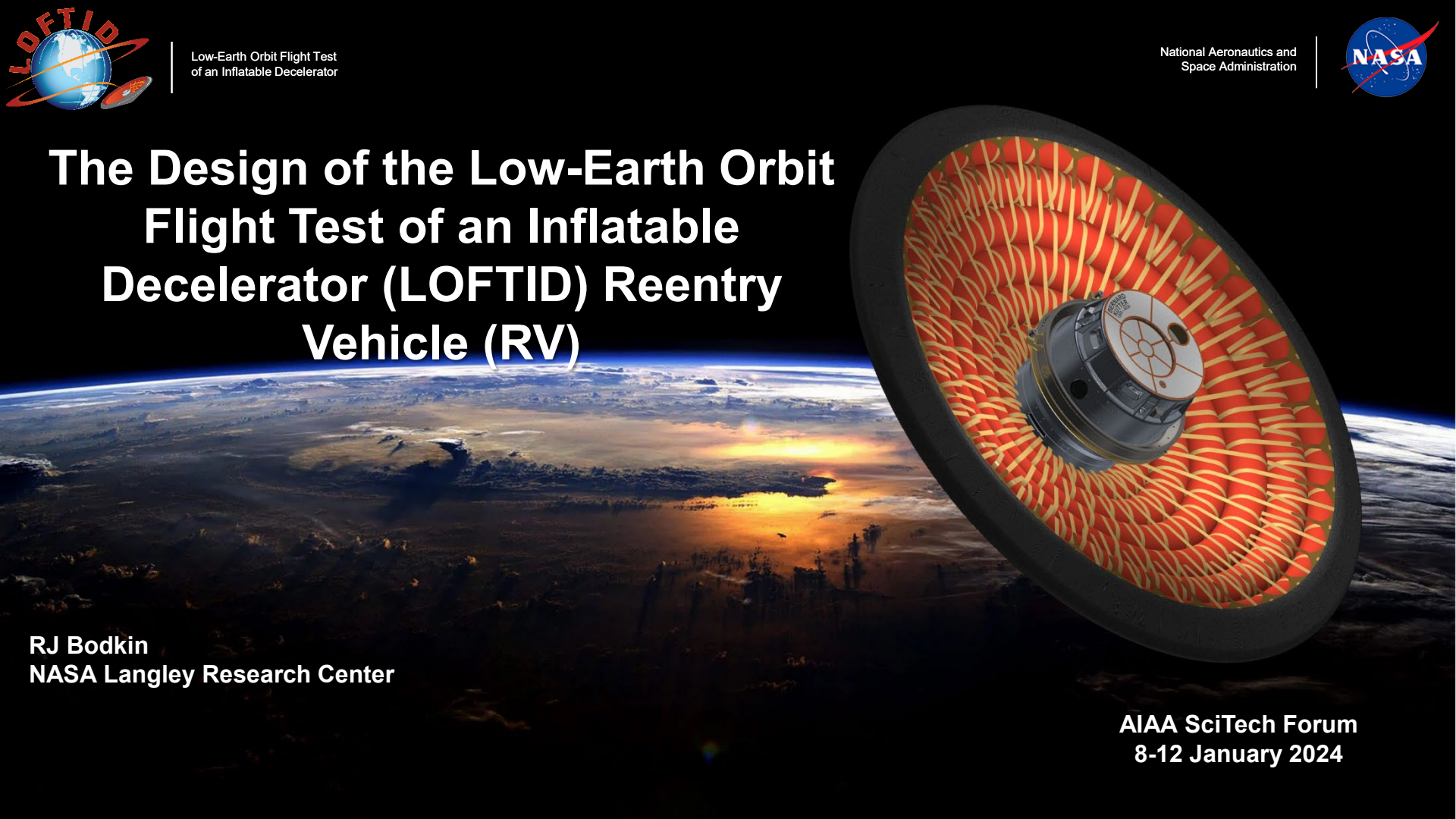

The Design of the Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) Reentry Vehicle (RV)

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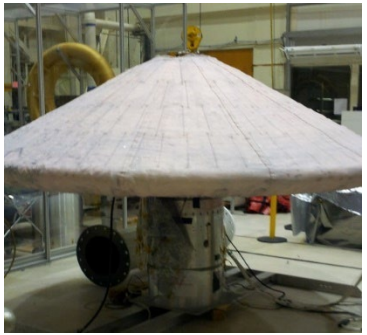
Brief History of HIADs (Hypersonic Inflatable Aerodynamic Decelerators)

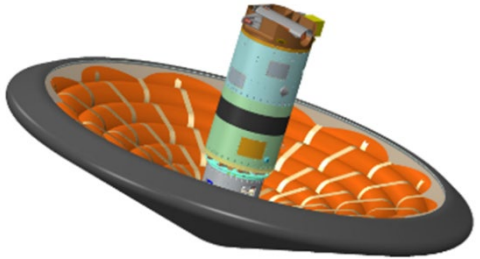
- Inflatable heatshields haver been sporadically researched since the mid-1960's

- IRVE (Inflatable Reentry vehicle Experiment)
  - Began 2003
  - Launched September 6, 2007
  - Launch vehicle Anomaly
- PAIDAE (Program to Advance Inflatable Decelerators for Atmospheric Entry)
  - Ground Program to looking for improved materials and structures
  - Began in 2006
- IRVE-II
  - Launched August 17,2009
  - Successful Flight
  - Reflight of IRVE with lessons learned incorporated

Brief History of HIADs



- IRVE-3
  - Successful Flight Launched July 23, 2012
  - New structure and new CG off-set
  - Built spare center body that was assembled
- THOR (Terrestrial HIAD Orbital Re-entry)
  - Flight project intended to fly on Antares Commercial Resupply Mission
  - THOR was canceled after ORB-3 mishap
  - Introduced concept of ejectable data recorder and shroud separation system
- HULA (HIAD on ULA) Concept
  - Original study looking at orbital reentry
  - HULA progressed to LOFTID



LOFTID Concept of Operations

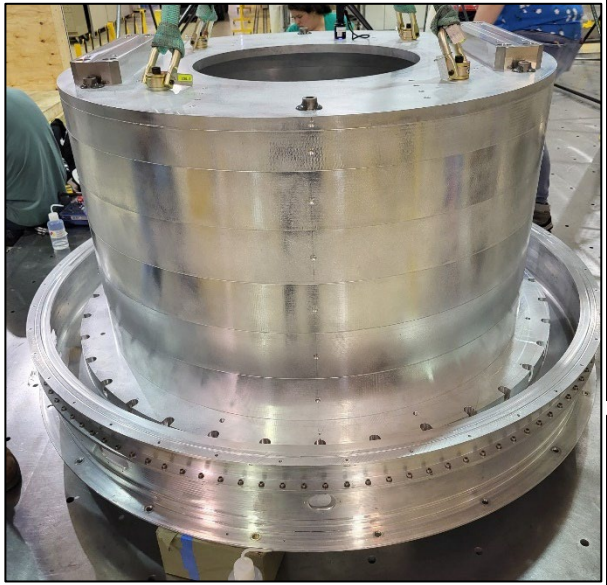
- RV Launches off on Atlas V with JPSS-2
- Centaur performs orbit adjustment burn
- Centaur de-orbits LOFTID
- Payload adapter jettisoned and LOFTID inflates
- Approximately 50,000 ft EDM is ejected
- Parachute deploys at approximately 10,000 ft

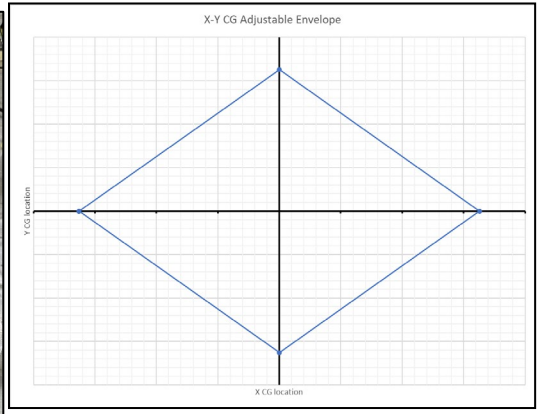
Payload Adapter Separation System (PASS)

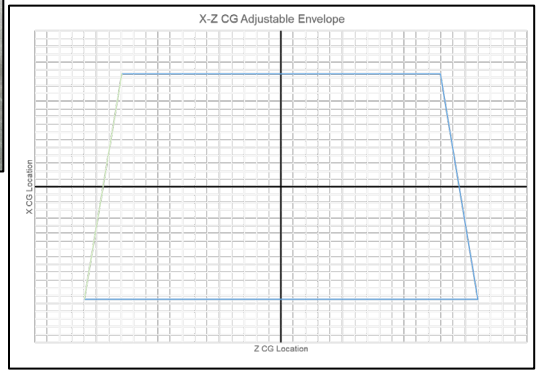
- LOFTID rideshare configuration
  - Payload Adapter Canister deployed prior to start of LOFTID mission
- Utilized ULA 1666S Separation System
- NASA Long Stroke Separation System
- 6x Constant Force Springs to provide positive force margin for full separation
- Webbing to react spring force against stowed aeroshell
- Inner Shroud to prevent damaging contact between PLA and stowed aeroshell

Mass Simulator

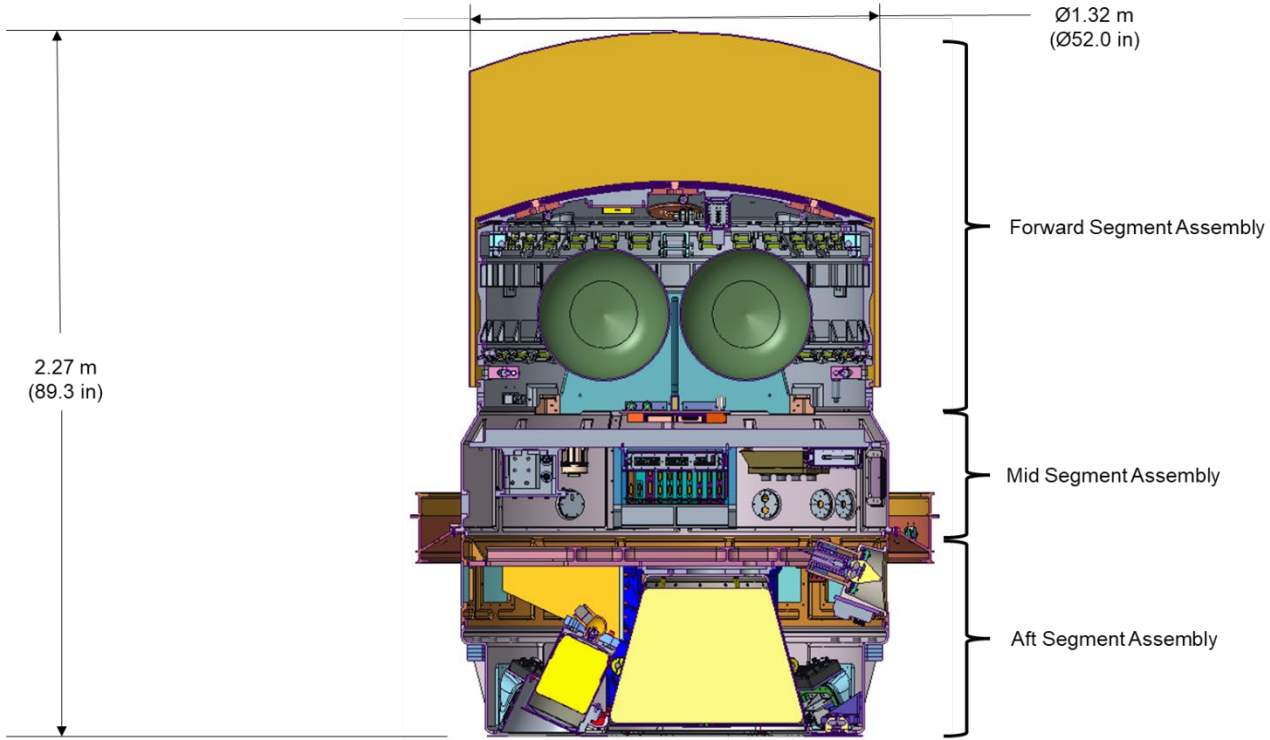
- Was required in the event Re-entry Vehicle (RV) suffered a late issue and was unable to launch
- Steel and Aluminum structure that used same launch vehicle interface as the RV
- Required to be ready prior to RV assembly
- Required large CG adjustment Range

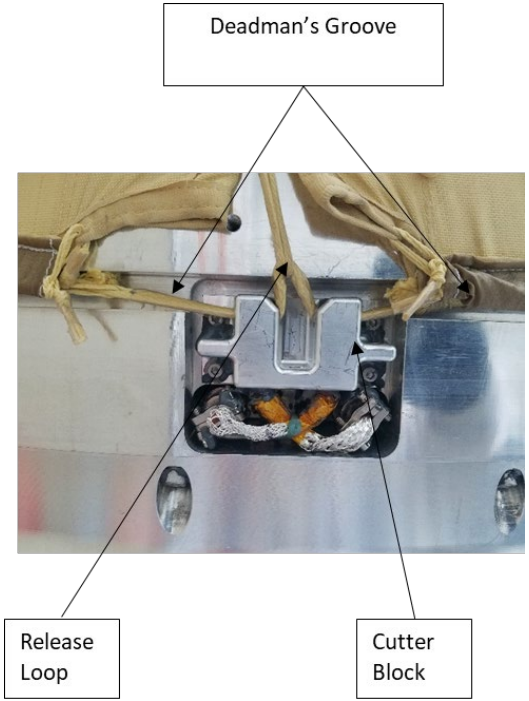




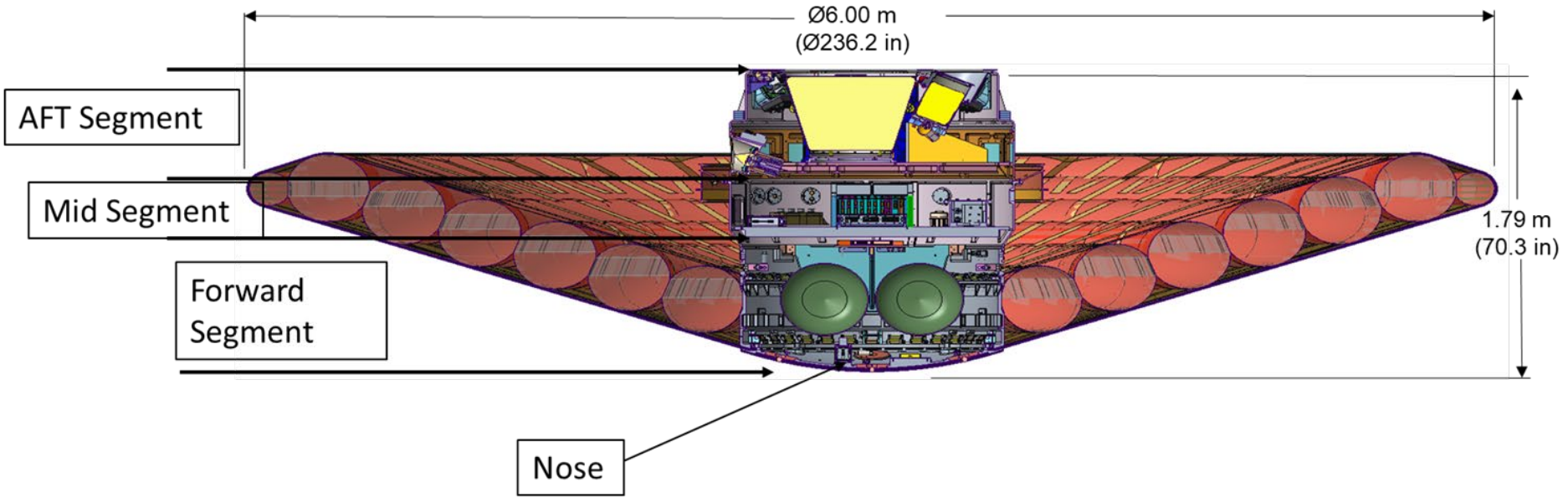


The Design of LOFTID (Packed)





The Design of LOFTID (Deployed)



LOFTID Segments

Forward Segment

- Forward Segment Radial Axial (Radax) Joint
- Inflation System and Mid-Segment Pass-Thru
- Aeroshell interface
- Rigid Nose Interface
- Segment comprised of multiple components
  - Forward Ring
  - Mid Segment Plates
  - Aft Ring

Mid Segment

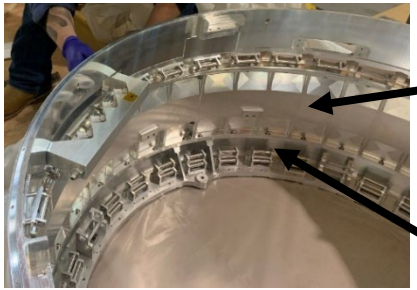
- Forward Segment Radax Joint
- Aft Segment Radax
- Vehicle Avionics
- Electrical pass throughs
- RV/LV interface
- Segment comprised of single ring

Aft Segment

- Aft Segment Radax Joint
- Parachute System
- Recovery Aids
- Camera System
- Communications Antennas
- Ejectable Data Recorder
- Segment comprised of 2 ring structures

LOFTID Segments

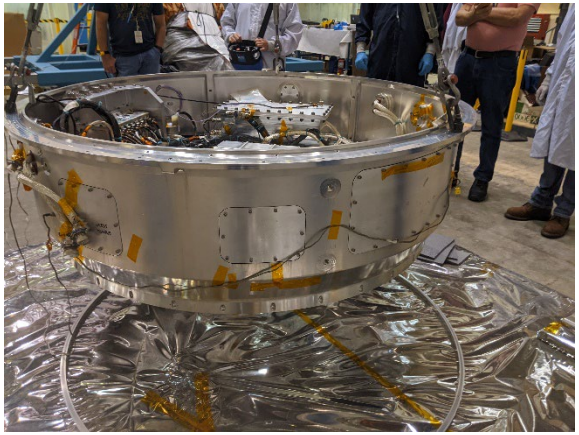
Forward Segment



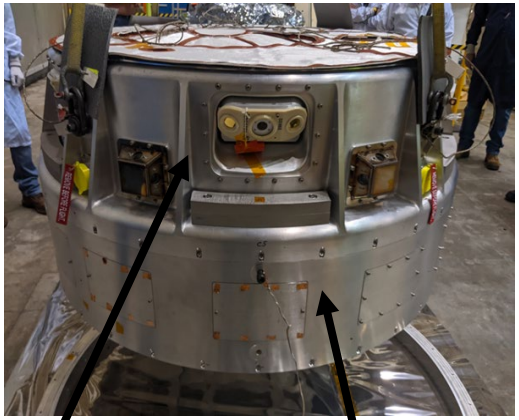
Mid-segment Plate

Forward Ring

Mid Segment



Aft Segment

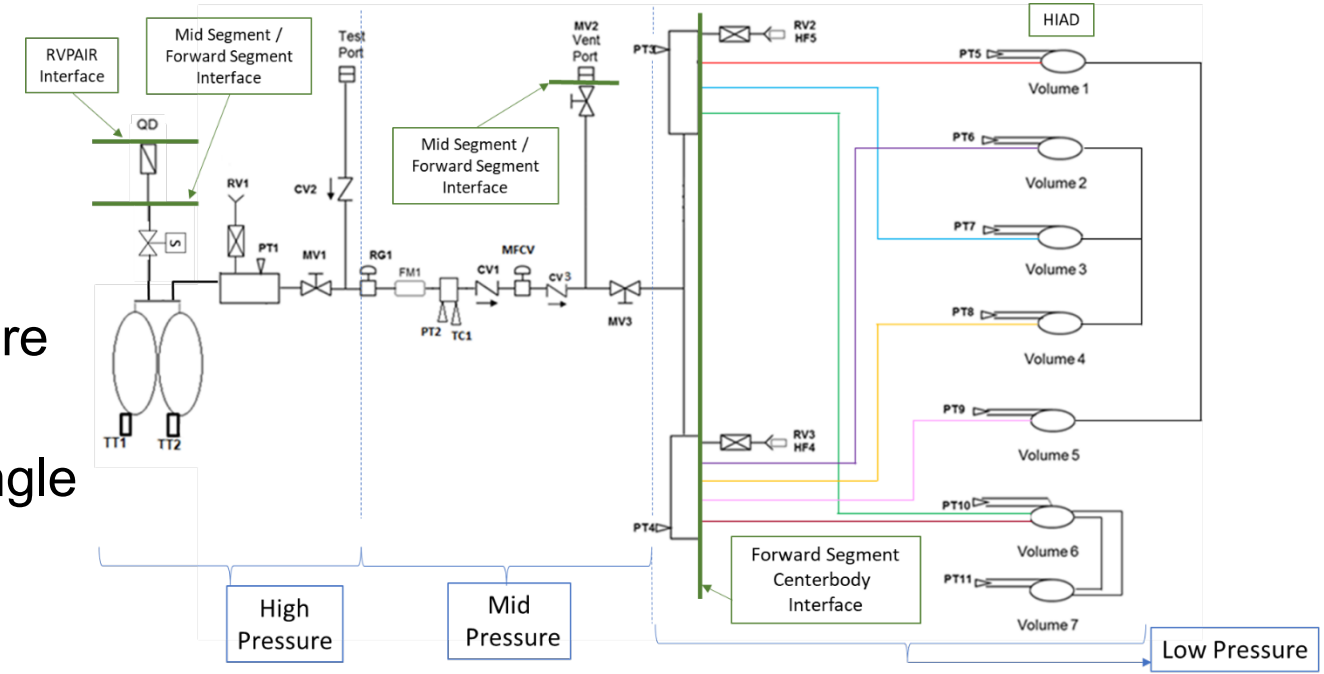


Aft Interface Ring

Aft Segment Ring

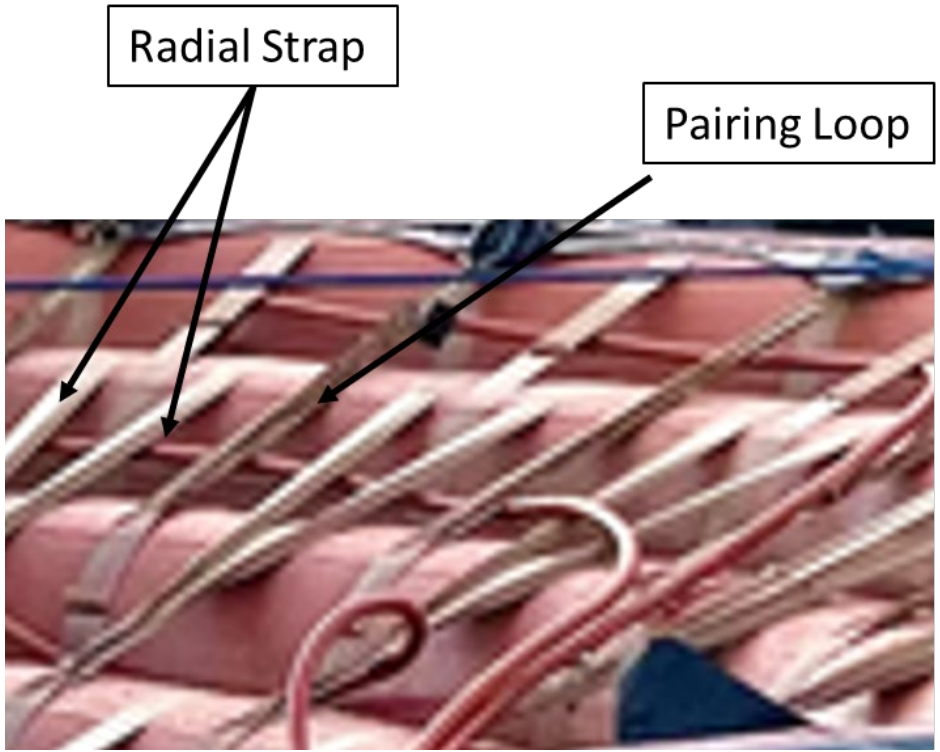
Forward Segment – Inflation System

- Most components IRVE-3 Heritage
- New set points
  - Regulator
  - MFCV
- Upsized low pressure relief valves
- Flowmeter blade angle change



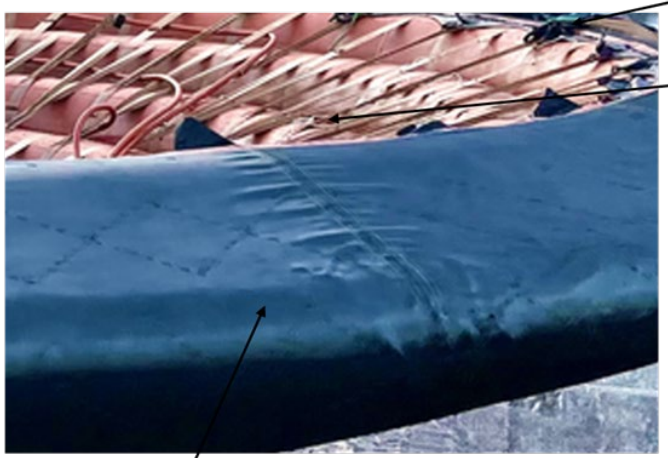
Forward Segment – Aeroshell Structure

- Stacked Tori design
  - First flown on IRVE-3
- Zylon webbing reacts reentry loads
- Zylon braid
  - Teflon Gas Barrier
  - RTV maintains braid organization during inflation
  - 2-Zylon cords provide in plane stiffness



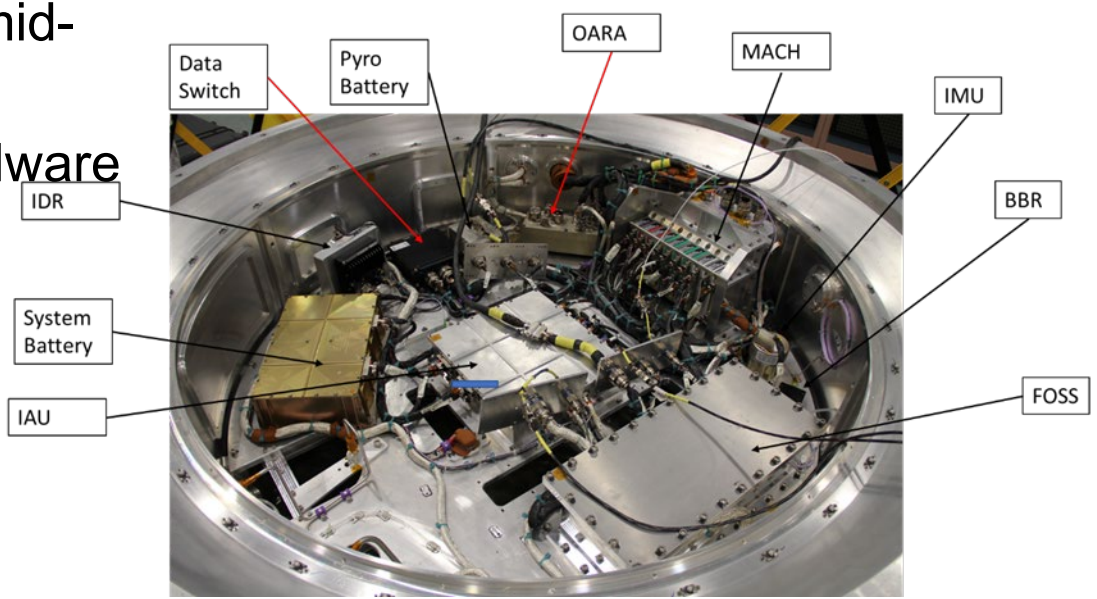
Forward Segment – Aeroshell Flexible Thermal Protection System (FTPS)

- FTPS Quilted Structure
  - Silicone Carbide
  - KFA5
  - Pyrogel
  - Teflon Zylon laminate gas barrier
- FTPS mounting
  - Forward mounting to a bar under rigid nose
  - Aft mounting to Cord loop

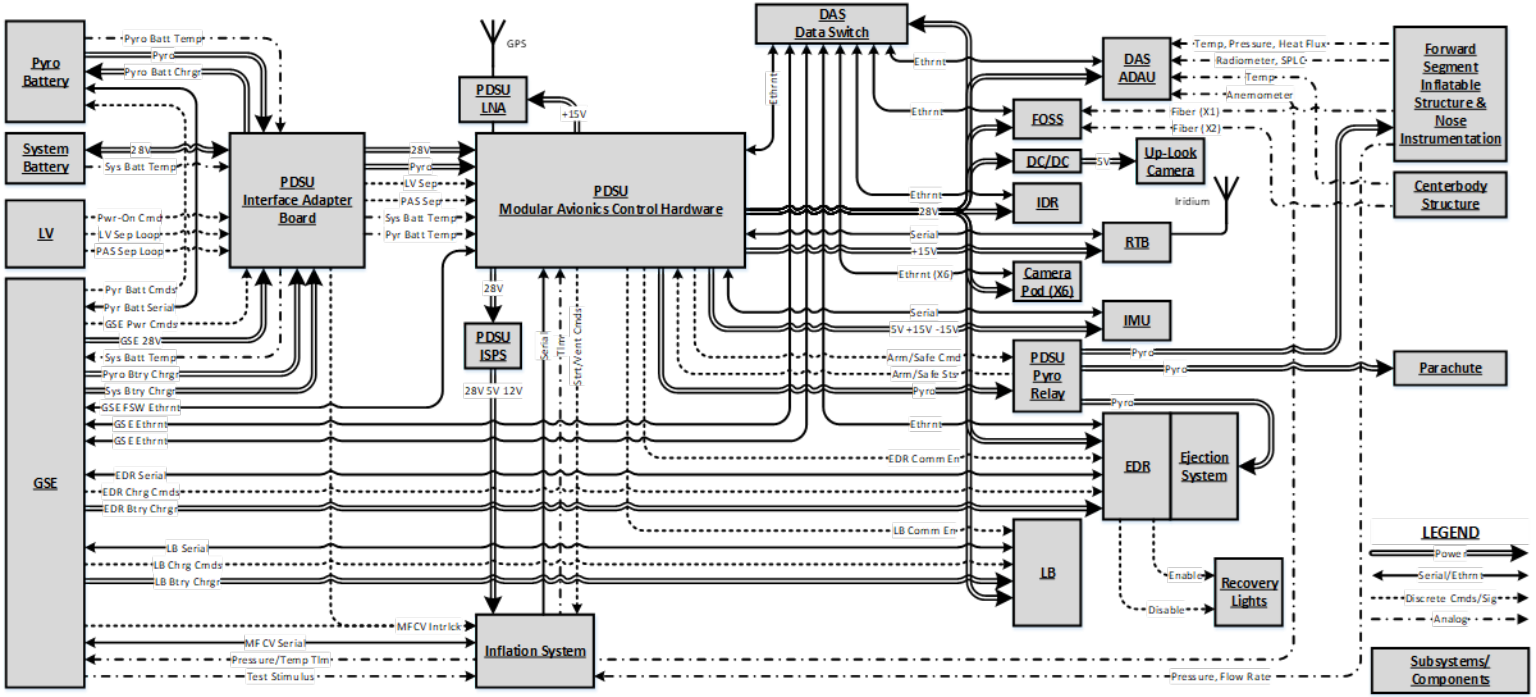


Mid Segment

- Majority of Avionics reside in mid-segment
- Modular Avionics Control Hardware (MACH) system
  - Flight Heritage
  - Served as event controller
  - Flight computer
- Fiber Optic Sensing System (FOSS)
  - LSP experiment flown to measure temperatures



Mid Segment - Avionics



Mid Segment - Avionics

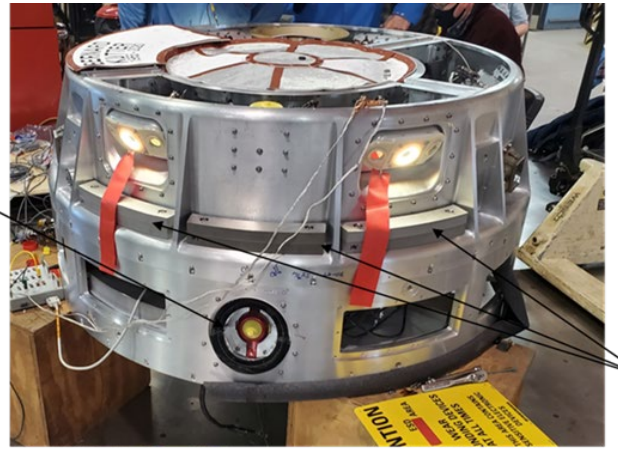
- Pyrotechnic Safing and Arming
  - Controlled by the MACH and Ordinance Arming Relay Assembly (OARA)
    - Inflation System and Release cutters inhibited by loop back that wasn't released until payload adapter released
    - EDR and Parachute inhibited by loop back connector until RV released from Centaur
- Aeroshell Data Acquisition Unit (ADAU)
  - Capture approximately 100 aeroshell measurements in flight
    - Mounted to rigid nose

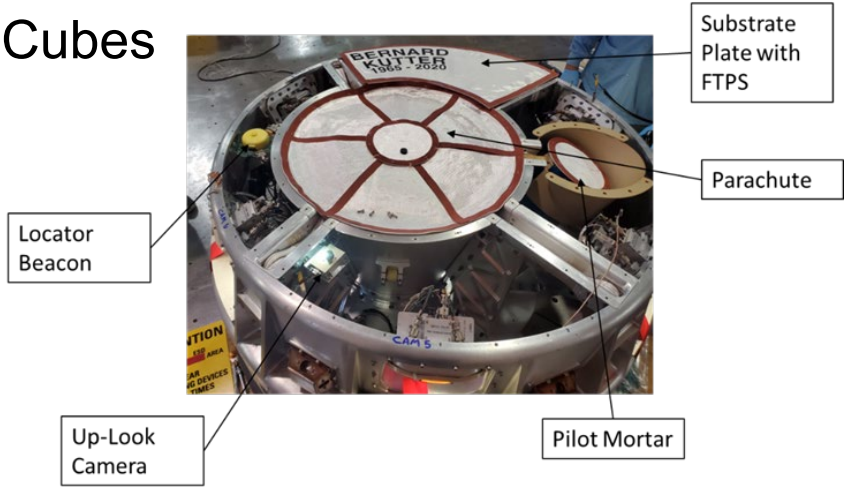
Mid Segment – Software

- Mach Software
  - NASA Core Flight System (cFS)
    - Modular layered platform for real time flight applications
- Data Recorder Software
  - Based on libPCAP
    - Widely used open-source library for network traffic capture
- Camera Controller Software
  - Based on GStreamer
    - Open-source multimedia framework
    - Hardware support for encoding and decoding of video streams

Aft Segment

- Contains 6 Camera pods designed by MSFC
  - 1 Visual Camera
  - 2 IR cameras
  - LED light ring
- Recovery Lights
- Corner Cubes

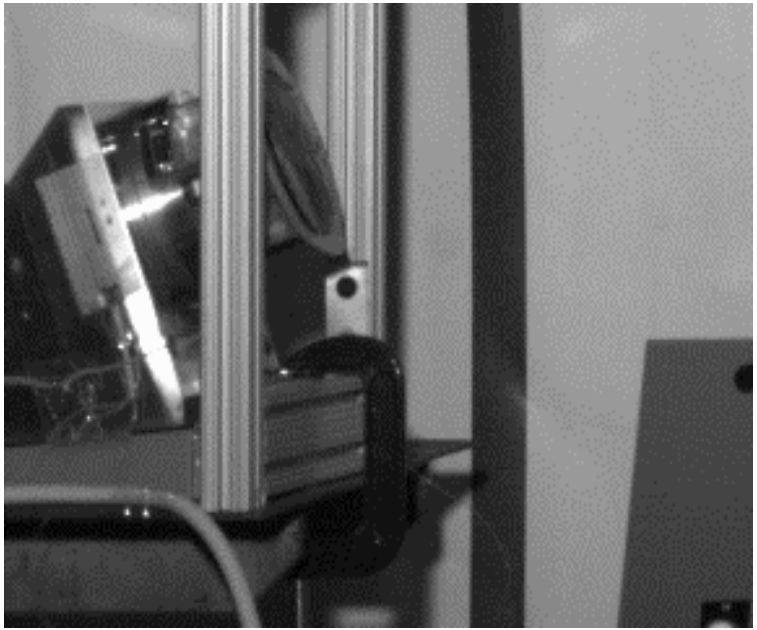




- EDR System
- Parachute System
- Up look Camera
- GPS and Iridium Antennas

Aft Segment – EDR

- Spring based system to deploy EDM
- System utilized a NEA
- NEA Stud remained with EDM

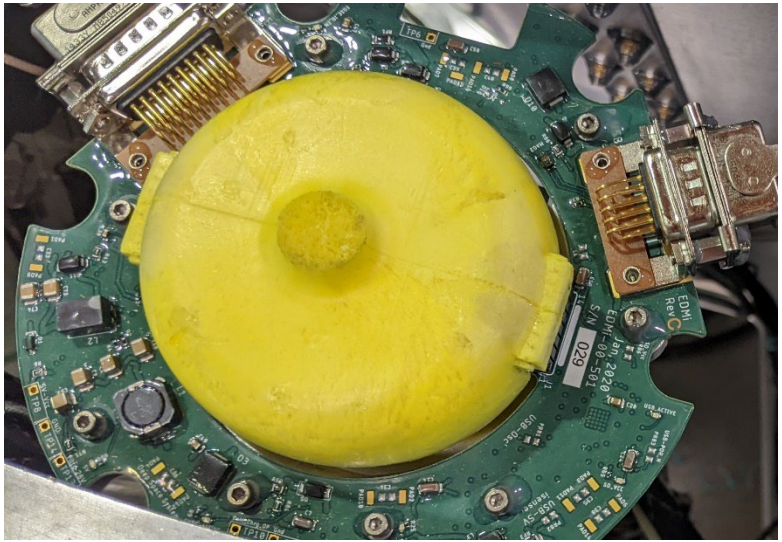


Aft Segment – EDM

- EDM was utilized extensively in the RV
  - Used as Ejectable Data Module
  - Used as Internal Data Module
  - Used as locator beacon
    - Modified OML
- Designed to land at terminal velocity
- Transmitted location via Iridium and LoRa network

Aft Segment – Beacons

- During Flight vehicle transmitted a minimum data set on the Real Time Beacon (RTB)
  - Used Iridium network
- Vehicle transitioned to Locator Beacon after parachute deployment
  - Locator Beacon modified data module
  - Transmitted position on two networks
    - Iridium Network
    - LoRa Network



Flight Results

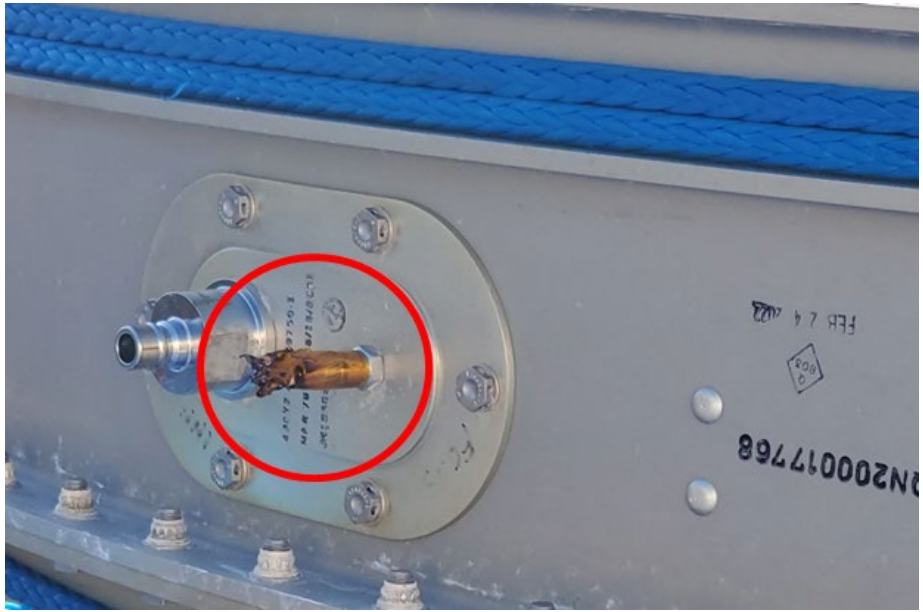
- Iridium data downlink was intermittent and only received after reentry
  - During ground testing was hit or miss if data would be transmitted
  - Lost communications for 1 hour during EDR recovery test in relatively calm seas
- Most data was captured
  - Full aeroshell performance data was captured
  - Software issue not found during pre-flight testing resulted in loss of some data

Flight Results

- EDR was tracked and recoverec after the RV
  - Data set matched onboard R\ storage until ejection
- RV was successfully recovered after landing within sight of the recovery vessel

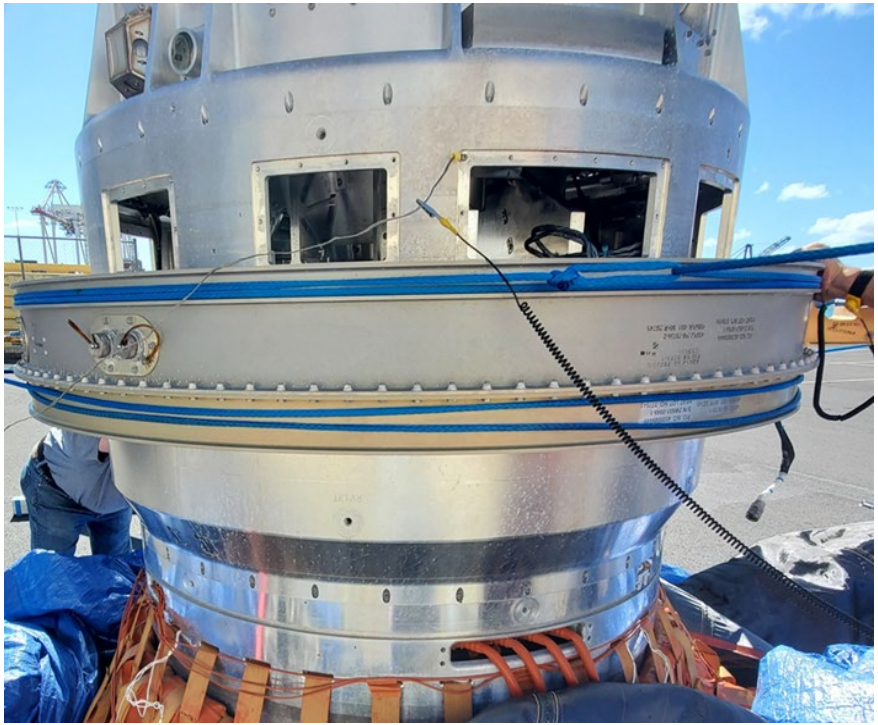
Flight Results

Tygon tubing - area circled shows blistering on the FOSS repressurization line



Kapton tape - note how pristine the surrounding area is compared to the tape

Flight Results



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Questions?

Thank you!

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