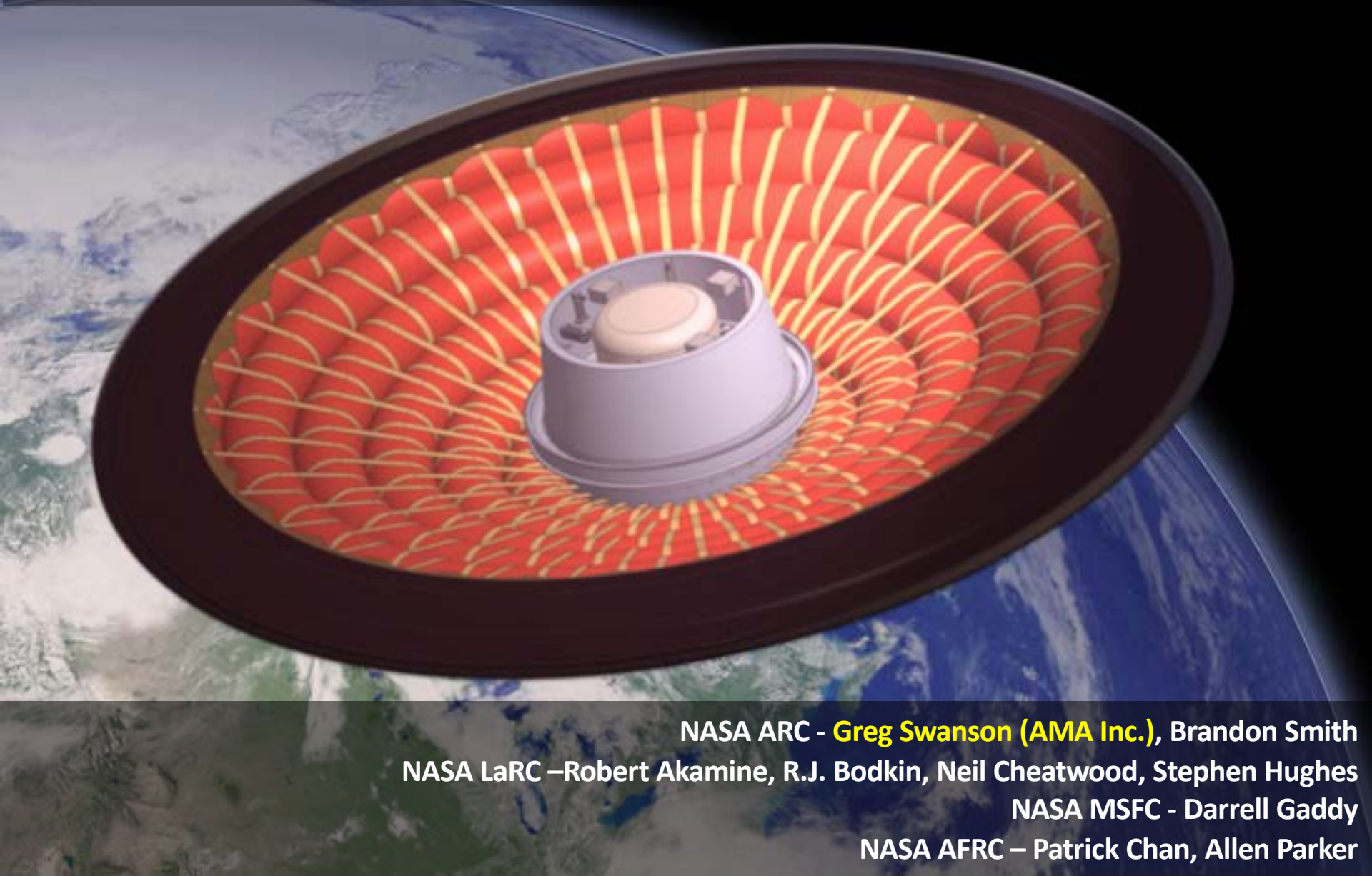
The HIAD Orbital Flight Demonstration Instrumentation Suite

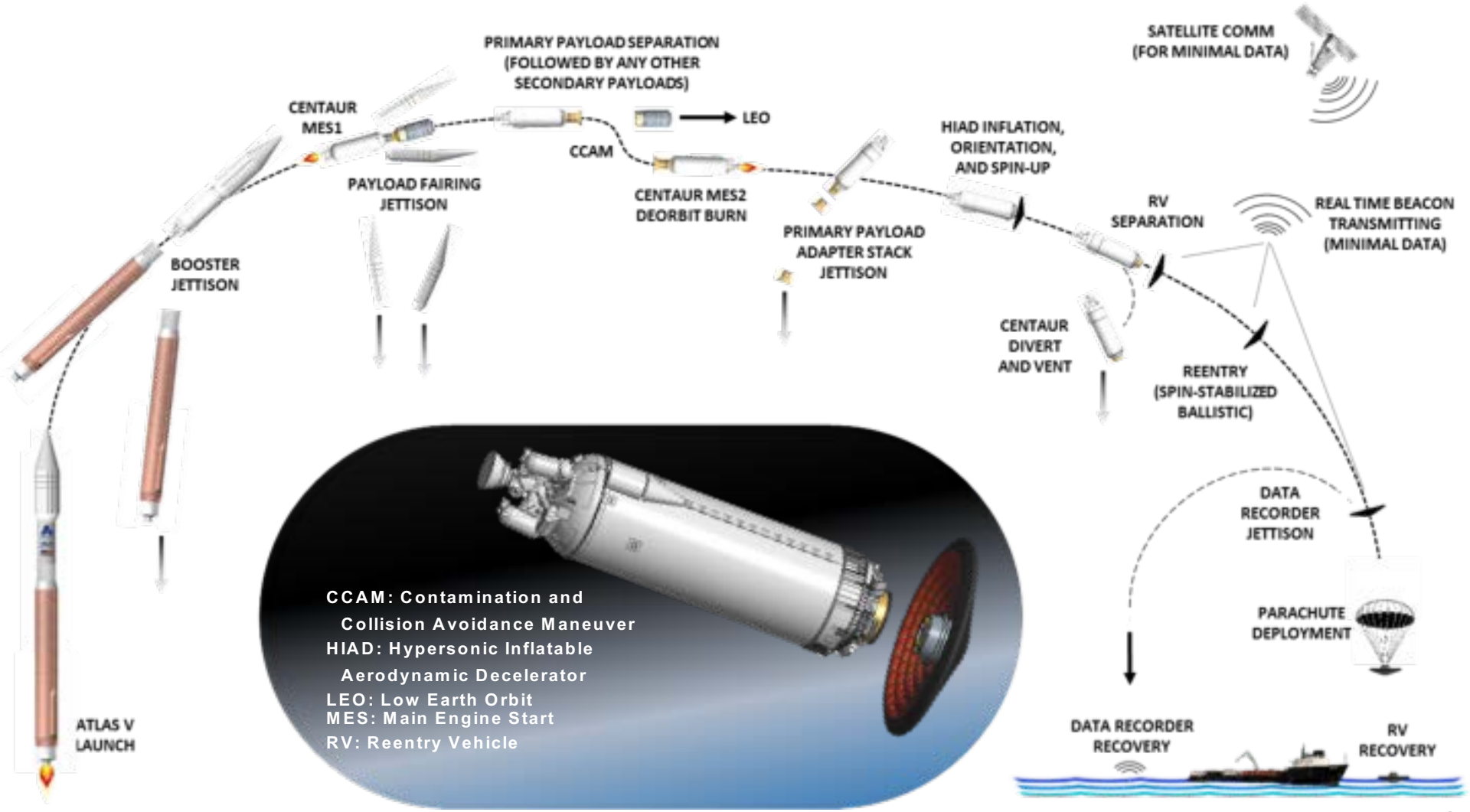
National Aeronautics and Space Administration



NASA ARC - Greg Swanson (AMA Inc.), Brandon Smith
NASA LaRC –Robert Akamine, R.J. Bodkin, Neil Cheatwood, Stephen Hughes
NASA MSFC - Darrell Gaddy
NASA AFRC – Patrick Chan, Allen Parker

LOFTID Mission

LeO Flight Test of an Inflatable Decelerator (LOFTID)



Measurement Objectives

LOFTID is a demonstration flight project that will be used to validate thermal and structural models, and mature understanding of the HIAD technology

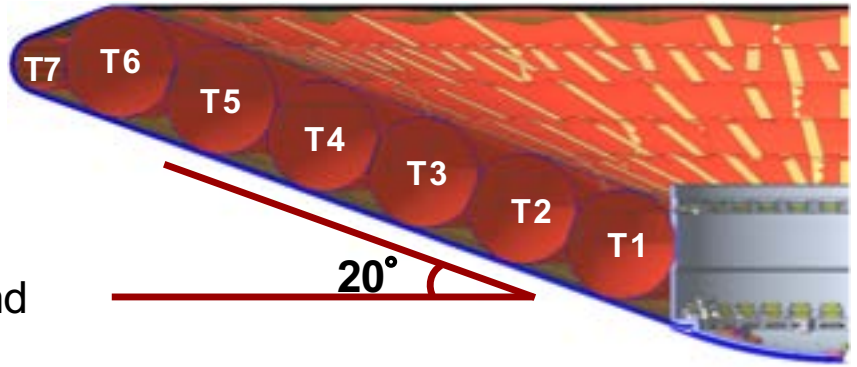
- IRVE-3 Flight Tested the Gen-1 Inflatable Structure, and Gen-1 F-TPS
  - Gen-1 Inflatable Structure Capability: 250˚C
  - Gen-1 F-TPS Capability: 35 W/cm^2
- LOFTID will Flight Test the Gen-2 Inflatable Structure and Gen-2 F-TPS
  - Gen-2 Inflatable Structure Capability: 400˚C
  - Gen-2 F-TPS Capability: 80 W/cm^2
- Unique Instrumentation Challenges
  - Embedding Sensors in a Flexible System
  - Measurement Location Knowledge
  - Aeroshell Do No Harm
- Key Performance Measurements
  - Aerothermal Response (Temp, Heat Flux)
  - Structural Response (Loads, Deflection)

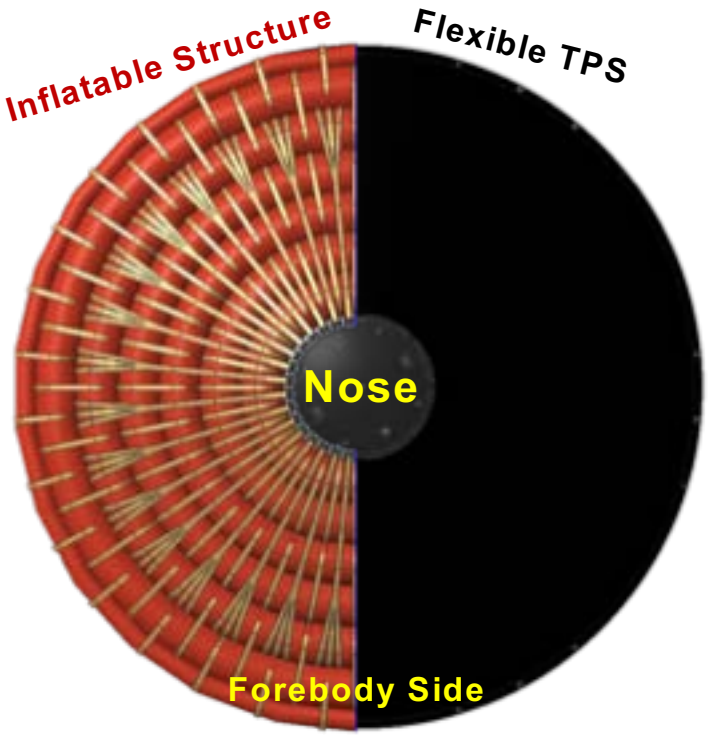
	IRVE-3	LOFTID	LEO Return	ISS Down Mass	ULA Engine Recovery	Humans to Mars
Diameter (m)	3	6	<6	8-12	12	18.8
Forebody Geometry (deg)	60	70	60-70	60-70	60-70	70
Entry Mass (kg)	330	1700	<1500	<5000	12000	56000
Entry Velocity (km/s)	2.7	7.1	7-7.5	7-7.5	4-6.5	6.2
Peak Heat Rate (W/cm2)	15	60	<50	30-40	<30	40

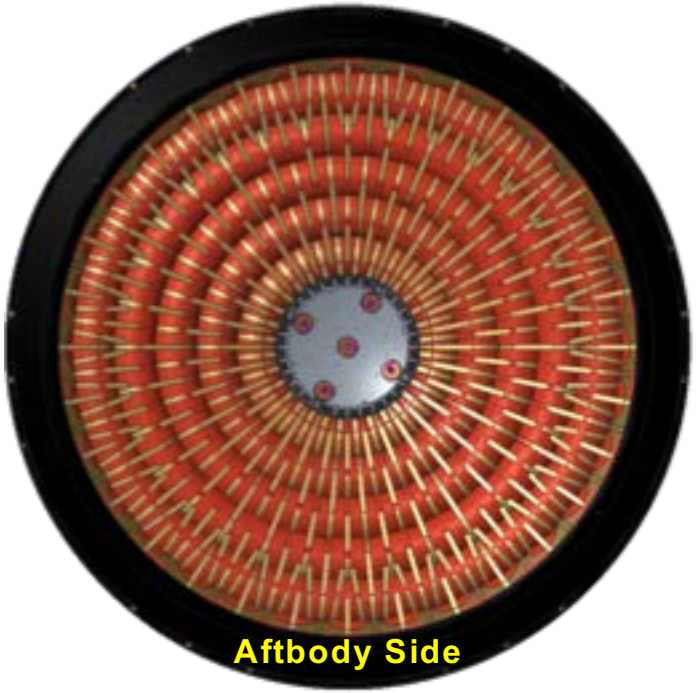
Aeroshell Design

6m HIAD Aeroshell

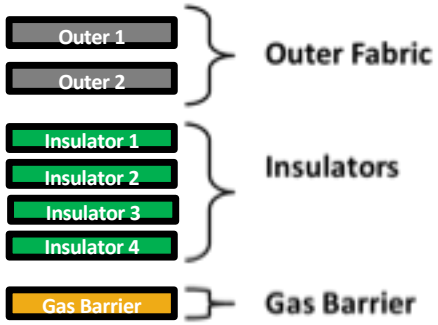
- Stacked torus inflatable structure
- Flexible TPS (F-TPS)
- 70-deg half-angle sphere-cone
- 6 structural tori, 1 shoulder torus
- Tori are formed by structural cords and bound together by high strength straps
- 4 centerbody attachment points at 32 locations



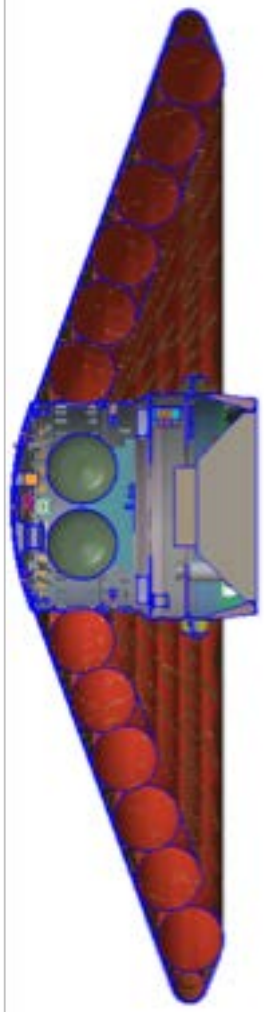




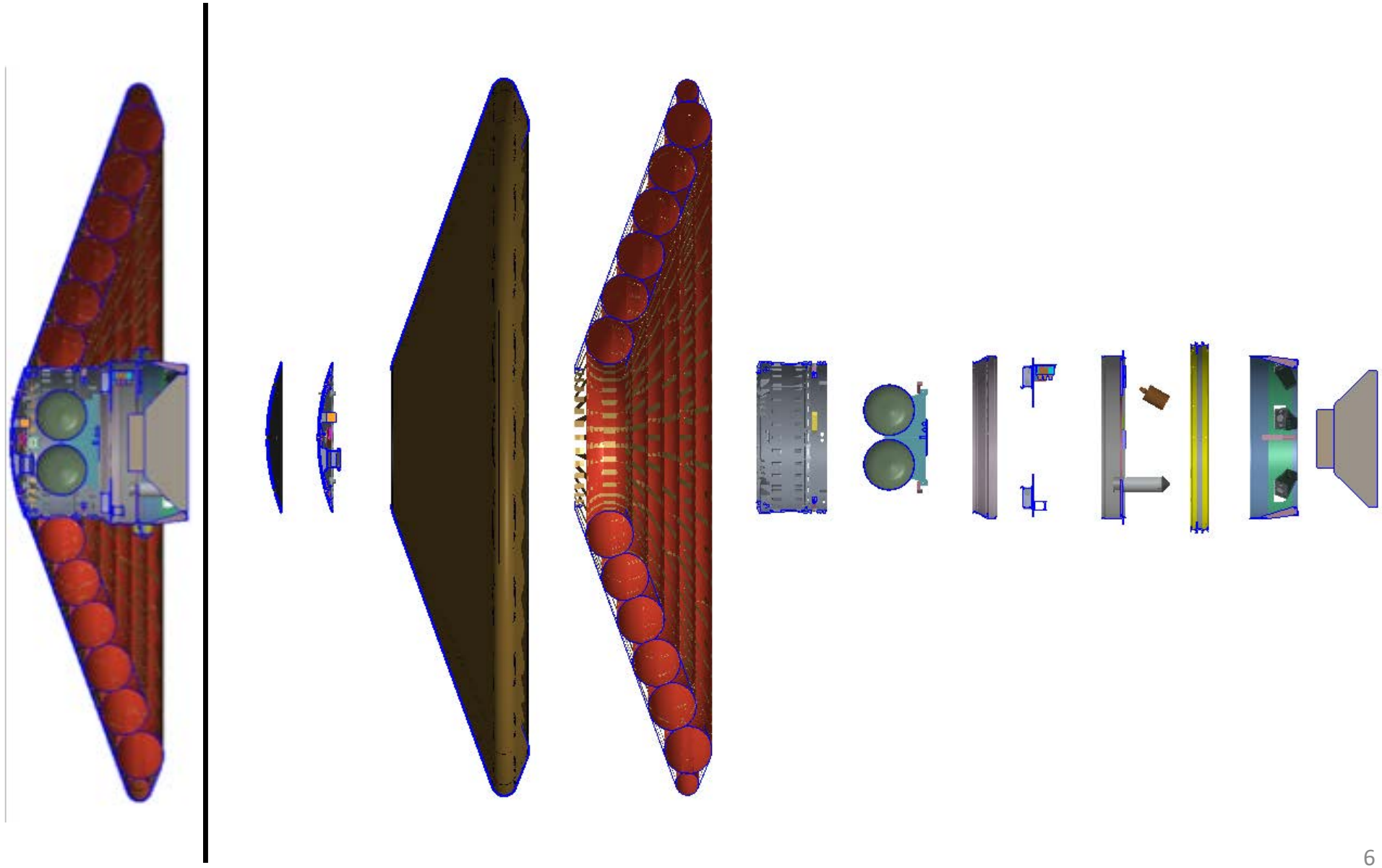
Flexible TPS Design



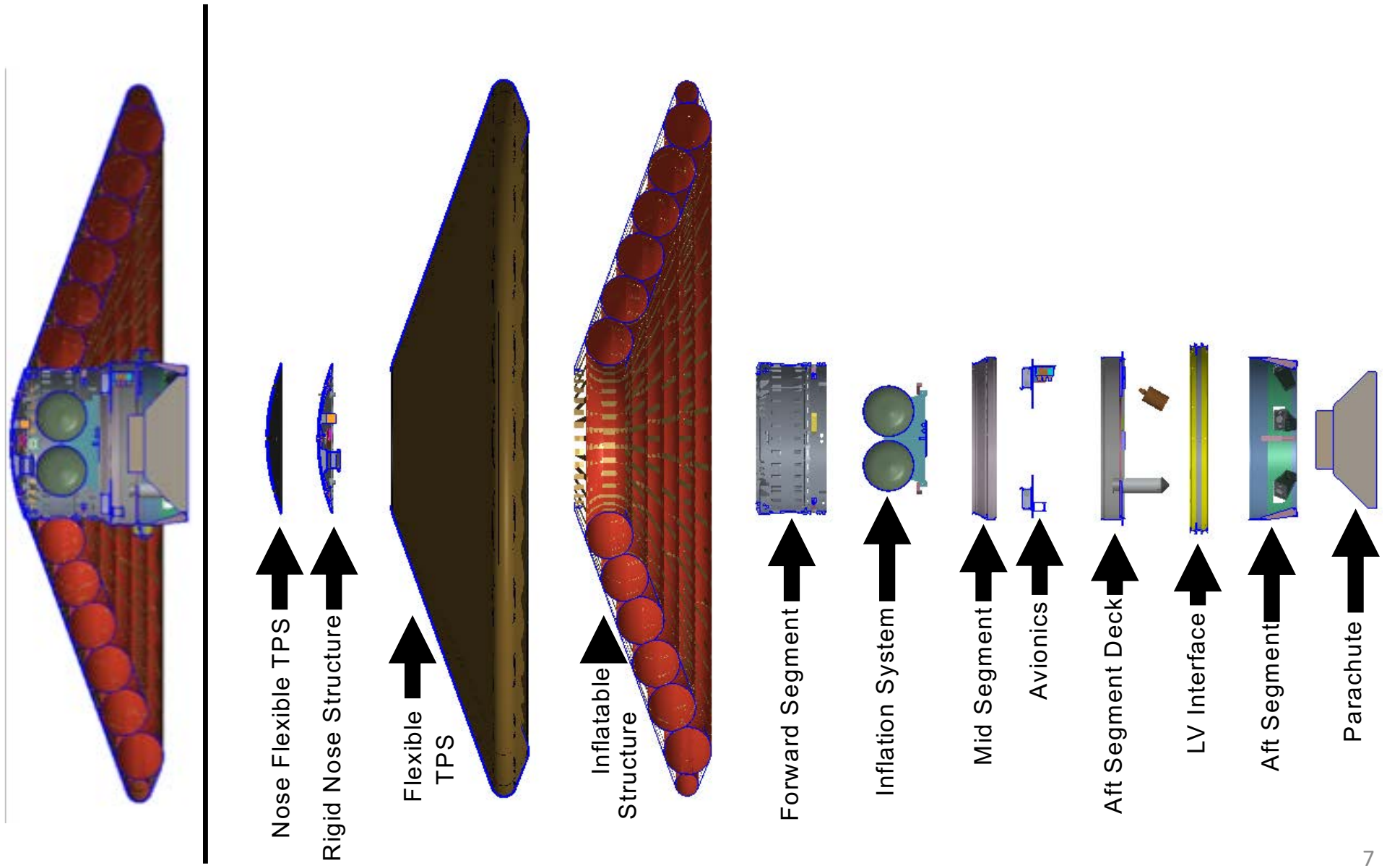
RV Instrumentation Overview



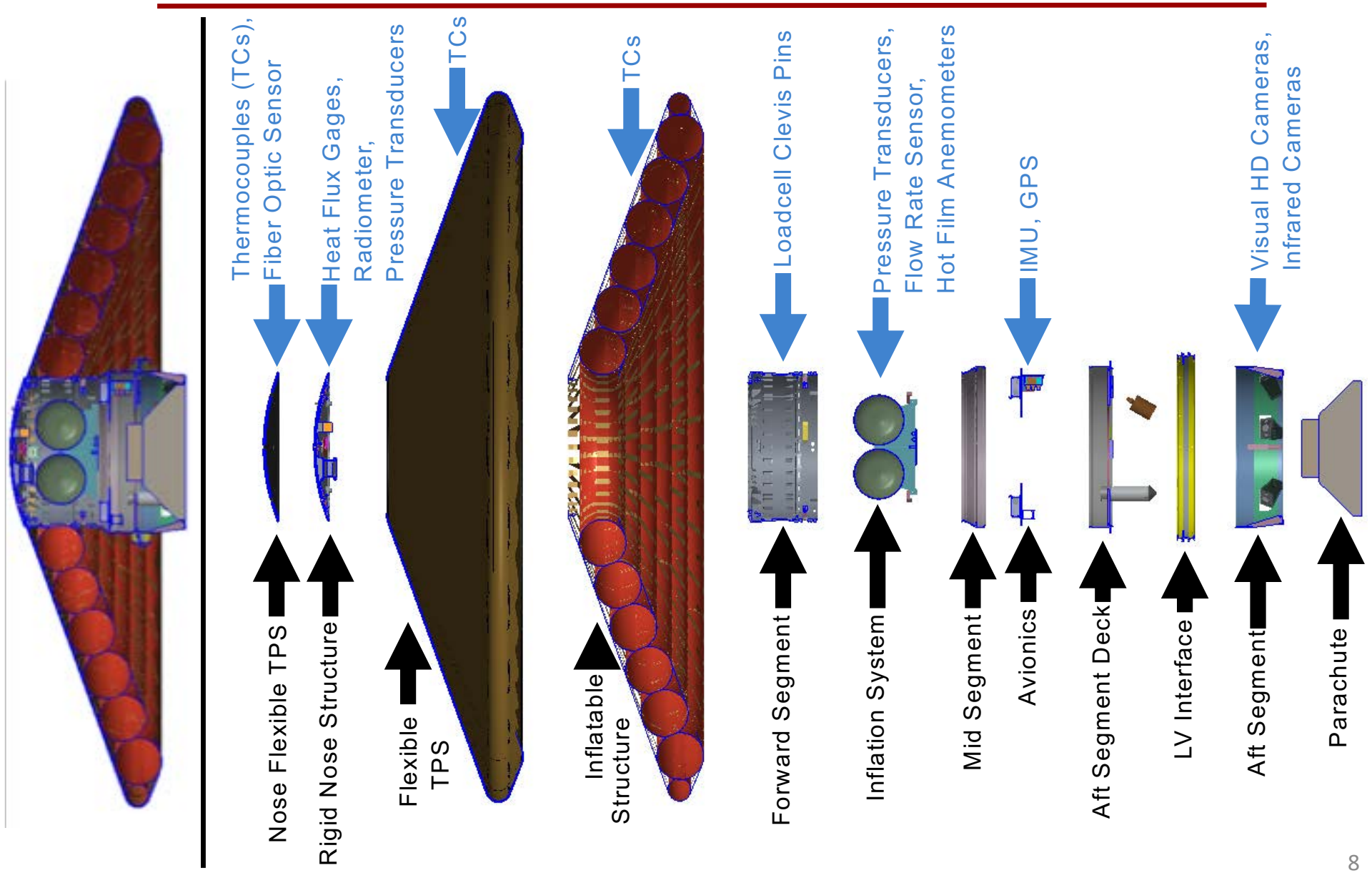
RV Instrumentation Overview



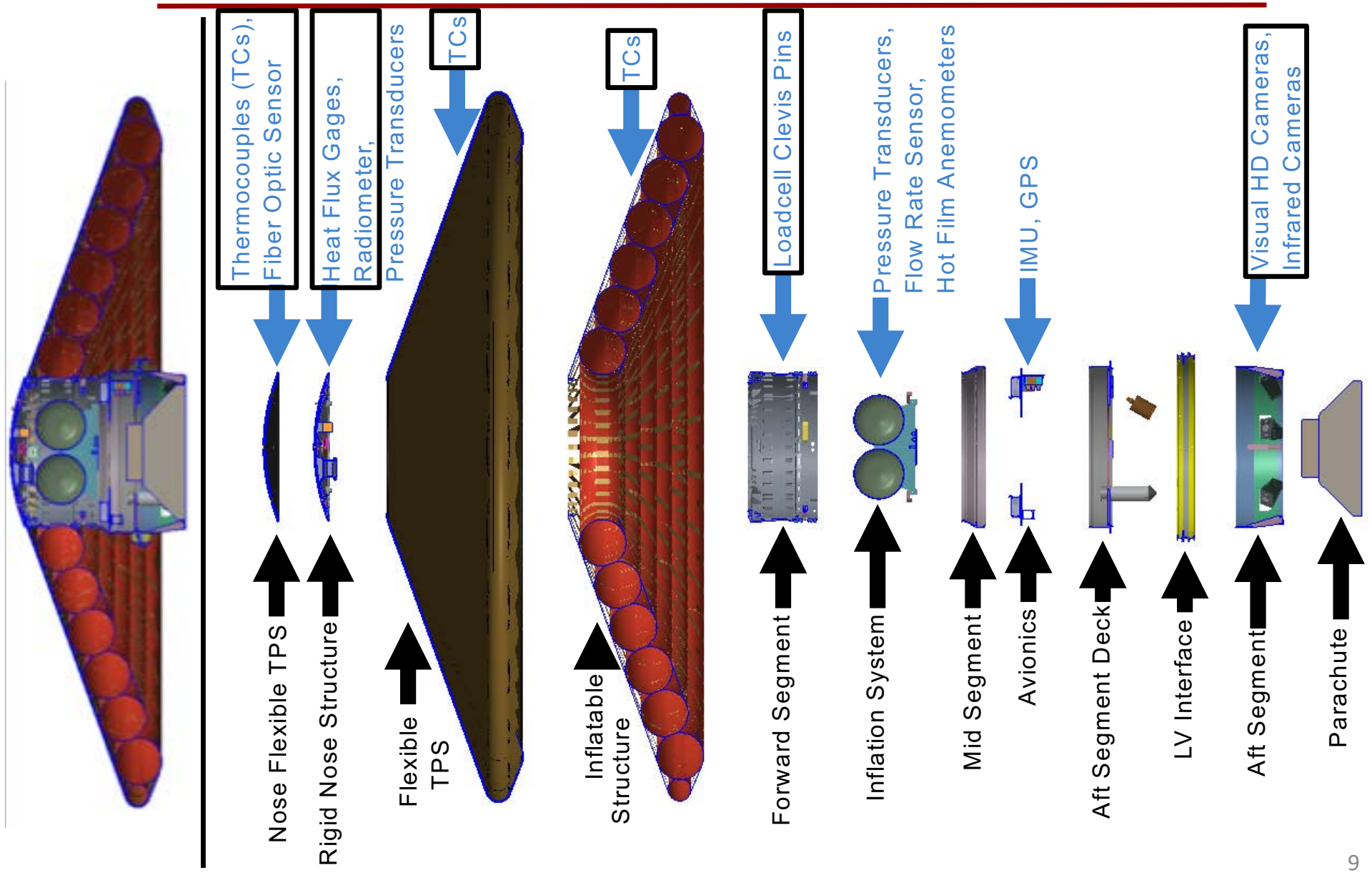
RV Instrumentation Overview



RV Instrumentation Overview

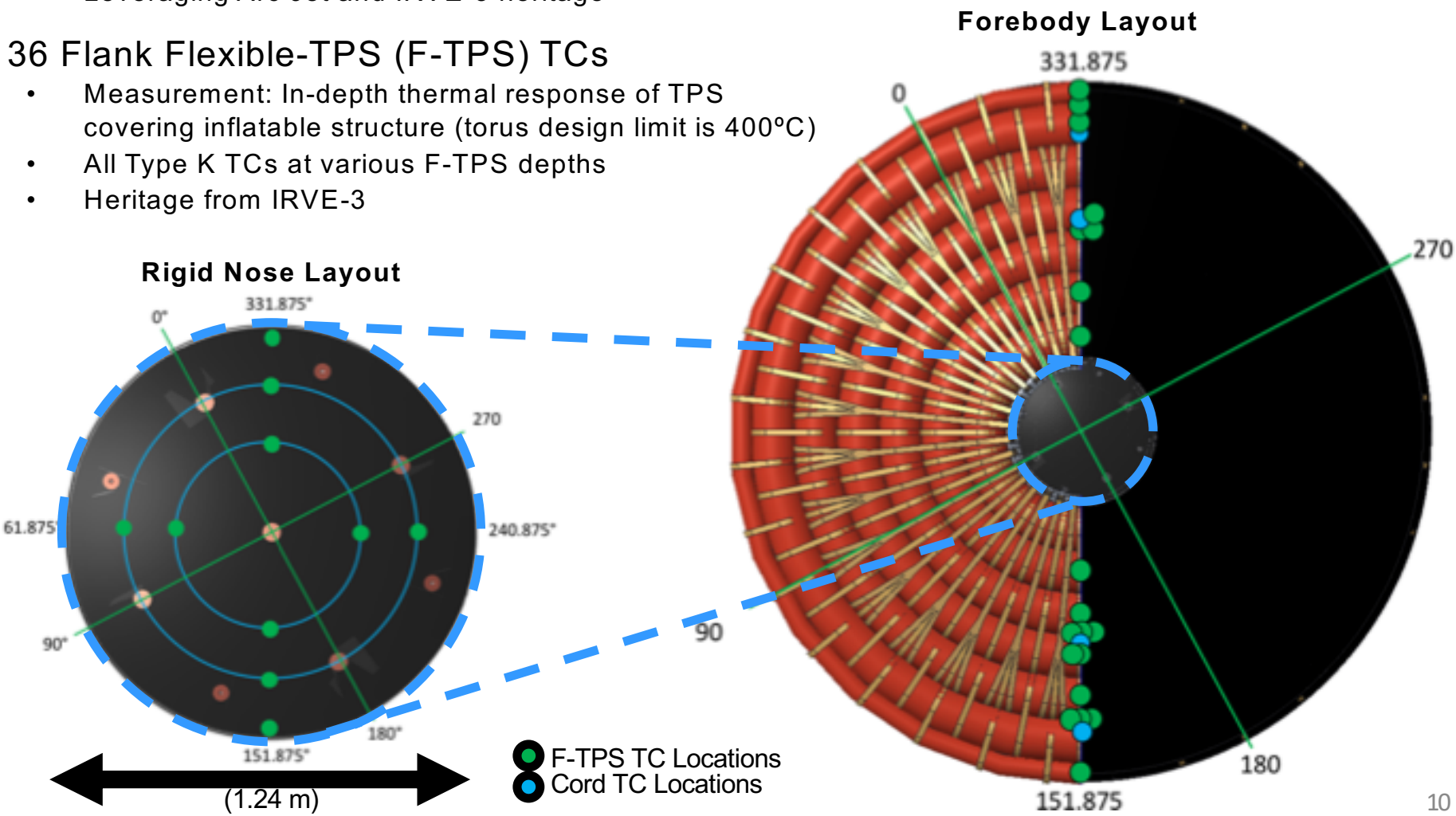


RV Instrumentation Overview



Forebody Thermocouples

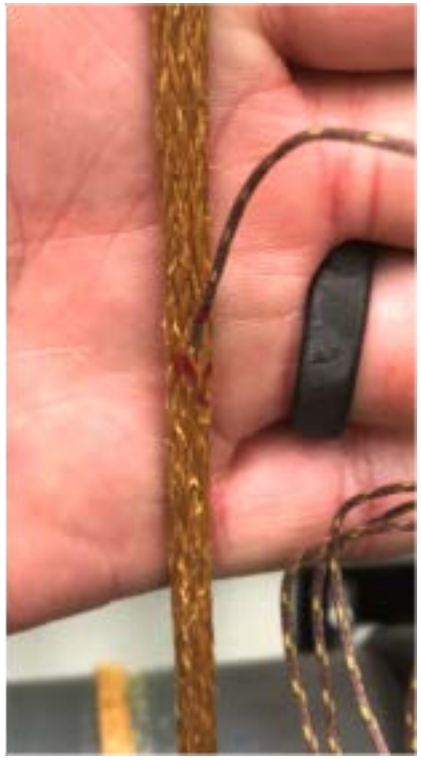
- 22 Nose Thermocouples (TCs)
  - Measurement: In-depth thermal response in region of predicted peak heating
  - 10 Type R TCs, 12 Type K TCs
  - Leveraging Arc Jet and IRVE-3 heritage
- 36 Flank Flexible-TPS (F-TPS) TCs
  - Measurement: In-depth thermal response of TPS covering inflatable structure (torus design limit is 400ºC)
  - All Type K TCs at various F-TPS depths
  - Heritage from IRVE-3



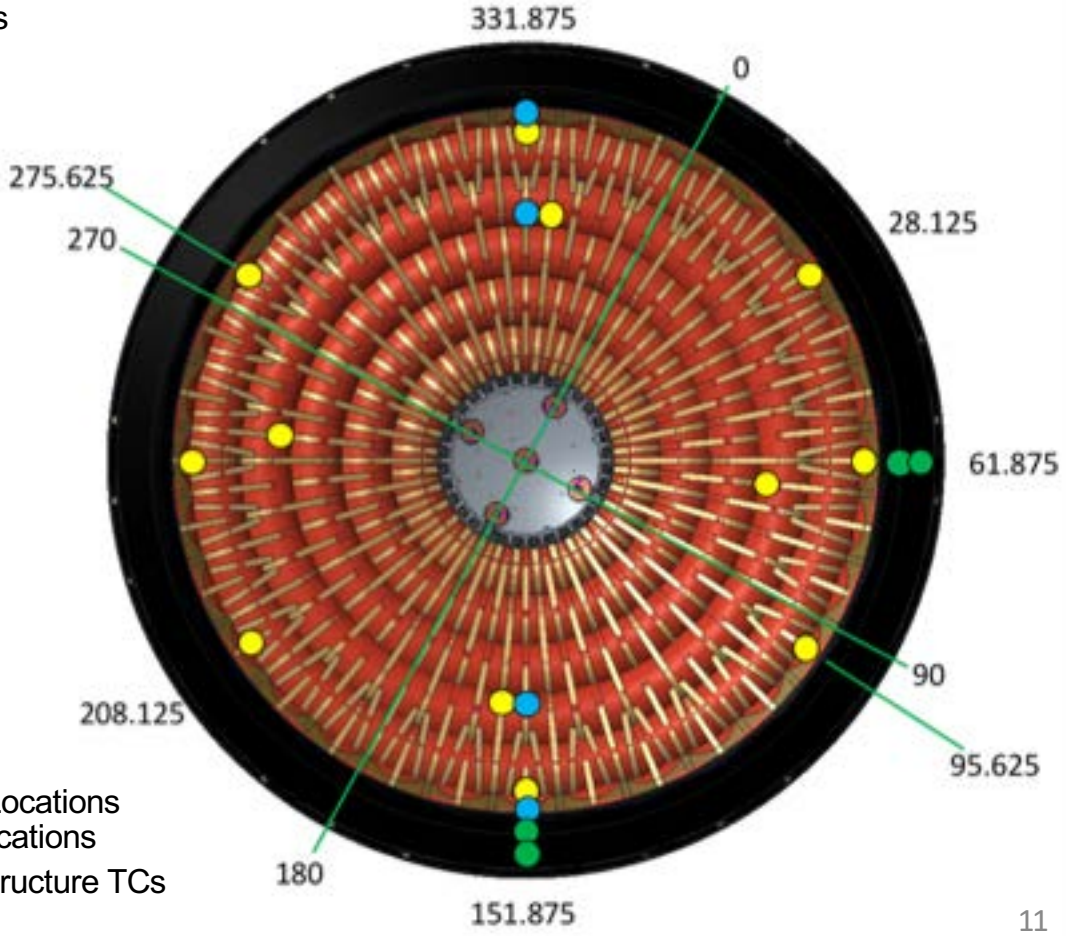
Wake-Side Thermocouples

- 24 Inflatable Structure TCs
  - Measurement: Temperature of key structural elements in the inflatable structure, also provides IR camera anchoring
  - All Type K TCs
  - Placed on straps, embedded in cords

TC Embedded in Structural Cord



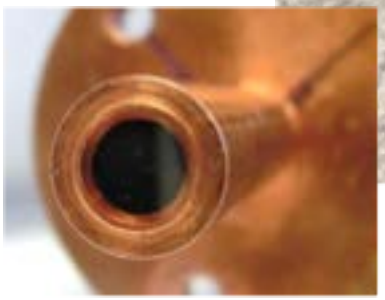
Wake-Side Layout



Heat Flux Sensors

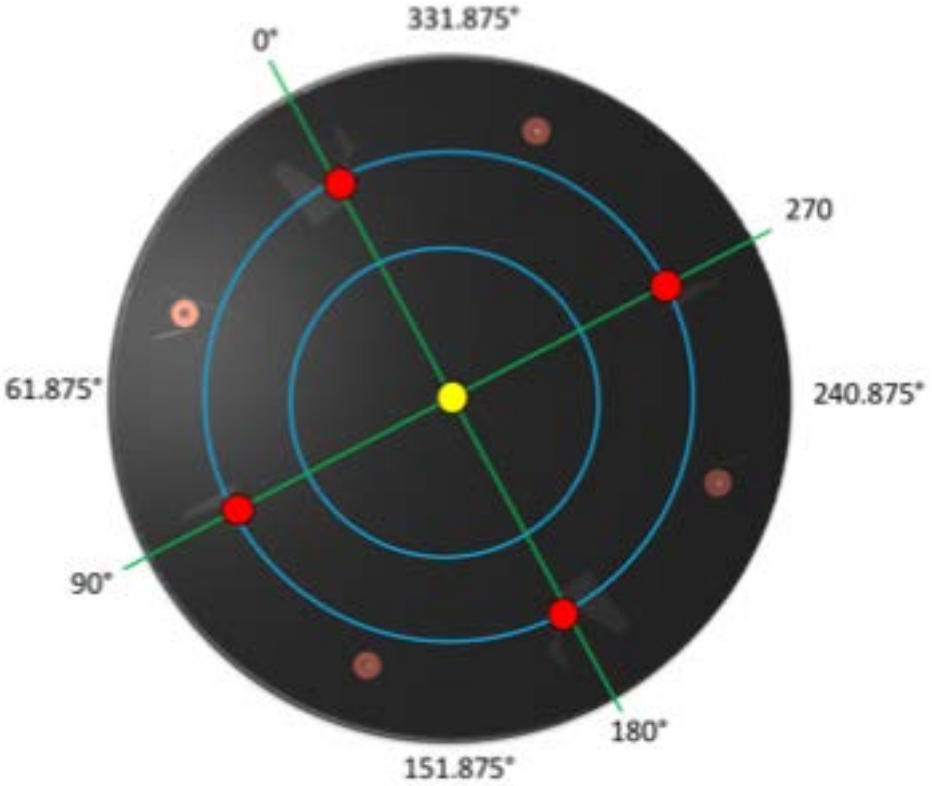
- 4 Total Heat Flux Sensors
  - Measurement: Measure heat flux and total heat load
  - Heritage design from IRVE 3
  - Schmidt-Boelter Gage
  - Pressure Port
- 1 Radiometer
  - Measurement: Radiative component of the total heat flux
  - New to HIAD, but has been qualified and will fly as part of MEDLI2
  - Schmidt-Boelter Gage, Sapphire Window
  - Pressure Port

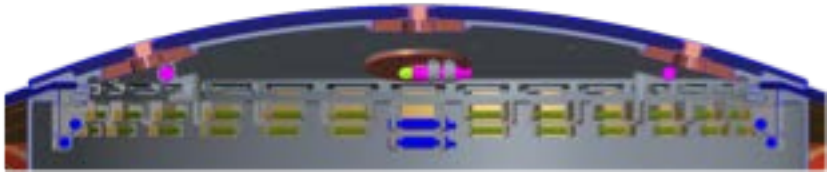
IRVE3 Heat Flux Gage



MEDLI2 Radiometer

Rigid Nose Layout

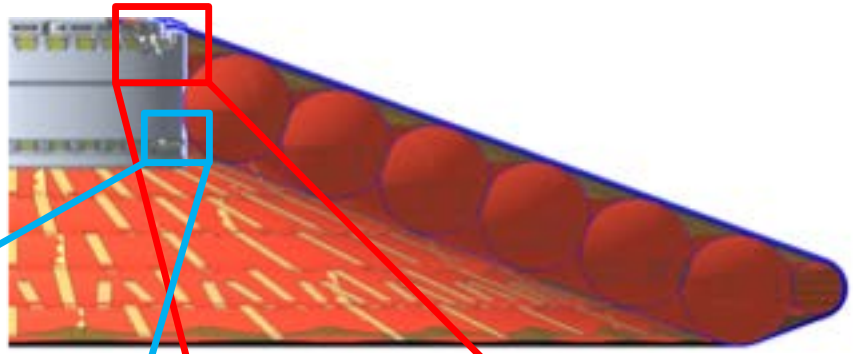


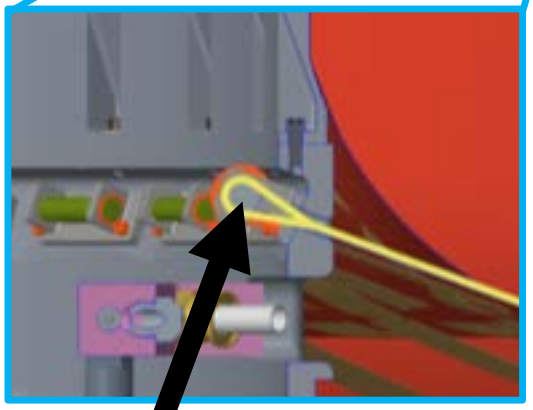


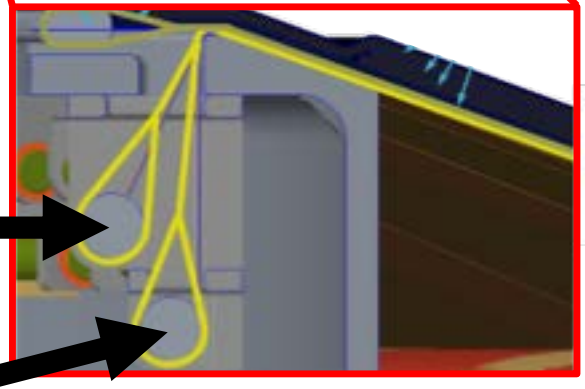
Cross-Section of Nose

Strap Loadcells

- 12 Strap Loadcell Clevis Pins
  - Measurement: Total load reacted at each cardinal position (0°, 90°, 180°, 270°)
  - 3 at each position: T1 Forward Strap, T1 Aft Strap, Radial Strap
  - Used extensively in HIAD ground testing







Aft T1 to CB Strap

Radial Pin

Forward T1 to CB Strap

Loadcell Clevis Pin

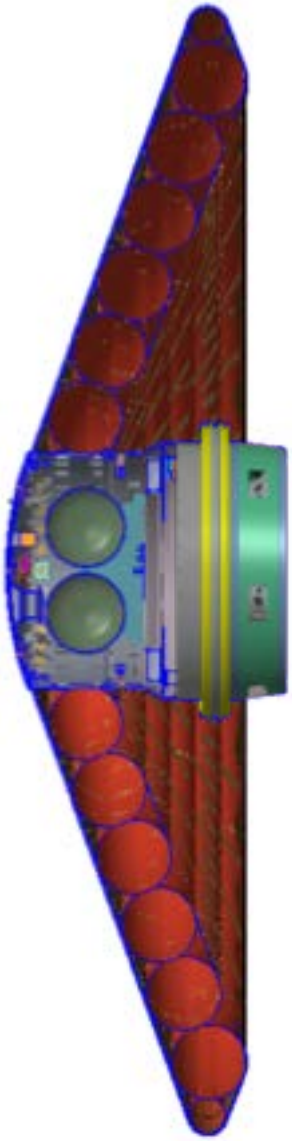
Cameras

- 6 Visual HD Cameras
  - Aeroshell deflection and observation (360˚ Coverage)
- 1 Up-Look camera
  - Launch vehicle separation and parachute deployment
- 12 Infrared (IR) Cameras
  - Aft-body temperature distribution (360˚ Coverage)

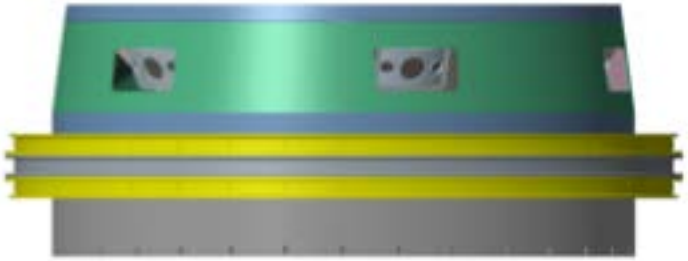
IR Camera

HD Aeroshell Camera

HD Up-Look Camera



Aft Deck Camera Mounting



6 Camera Pod Locations

Cameras

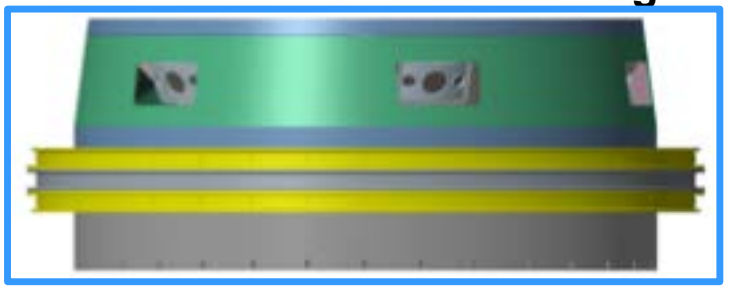
- 6 Visual HD Cameras
  - Aeroshell deflection and observation (360˚ Coverage)
- 1 Up-Look camera
  - Launch vehicle separation and parachute deployment
- 12 Infrared (IR) Cameras
  - Aft-body temperature distribution (360˚ Coverage)

IR Camera

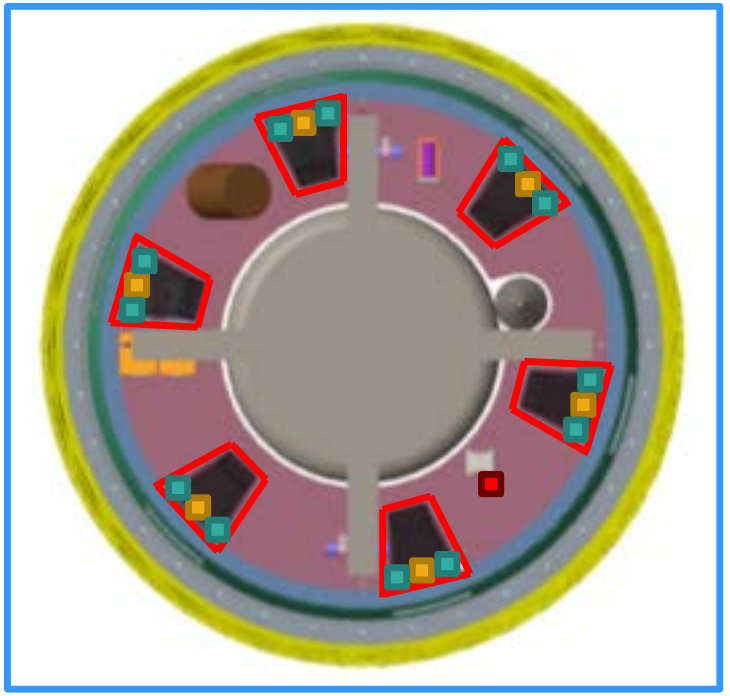
HD Aeroshell Camera

HD Up-Look Camera

Aft Deck Camera Mounting



6 Camera Pod Locations

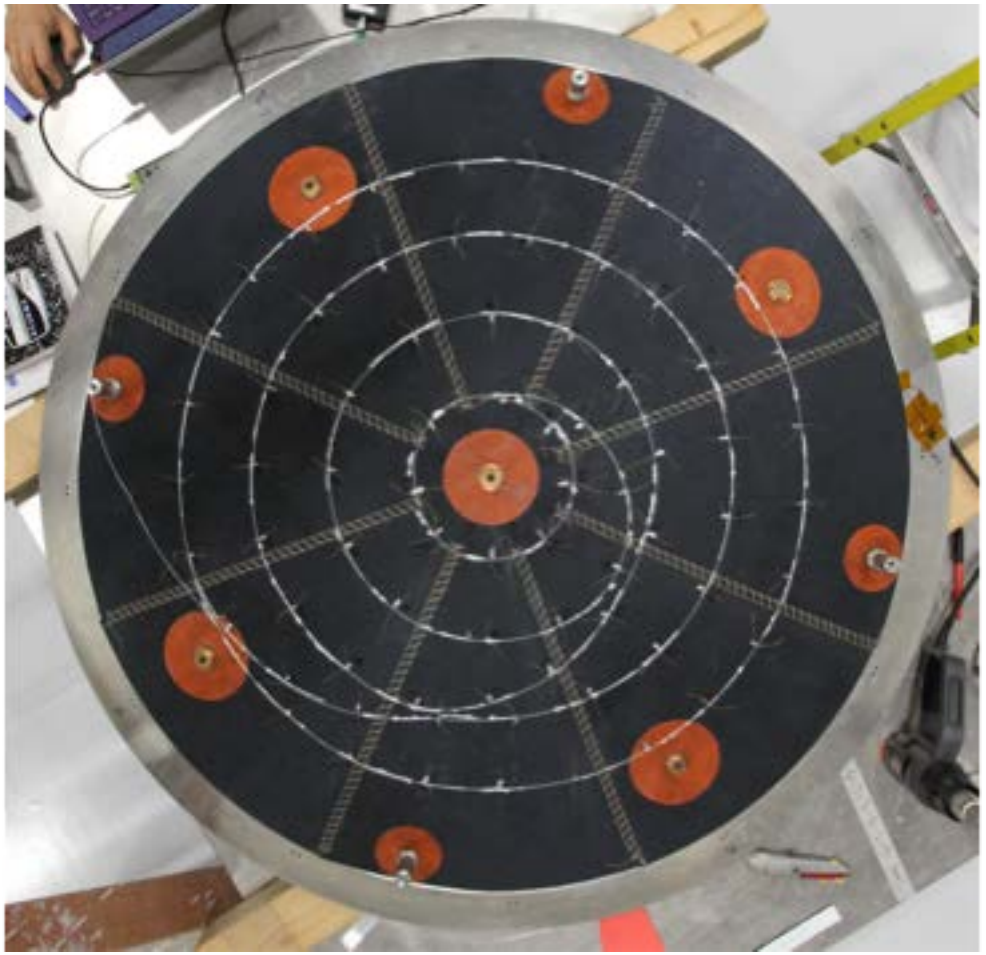


Developmental Instrumentation

2 Fiber Optic Strain Sensors

- Fibers are strain-isolated so they only sense temperature
- 1 Fiber on the rigid nose
- 1 fiber on centerbody
- Have been flown on test aircraft
- Being developed for use by LSP

Fiber Optic Strain Sensing Fiber in Lab



Fiber Optic Strain Sensing Fiber Integrated on EDU Nose in Semi-Spiral Pattern

Questions?