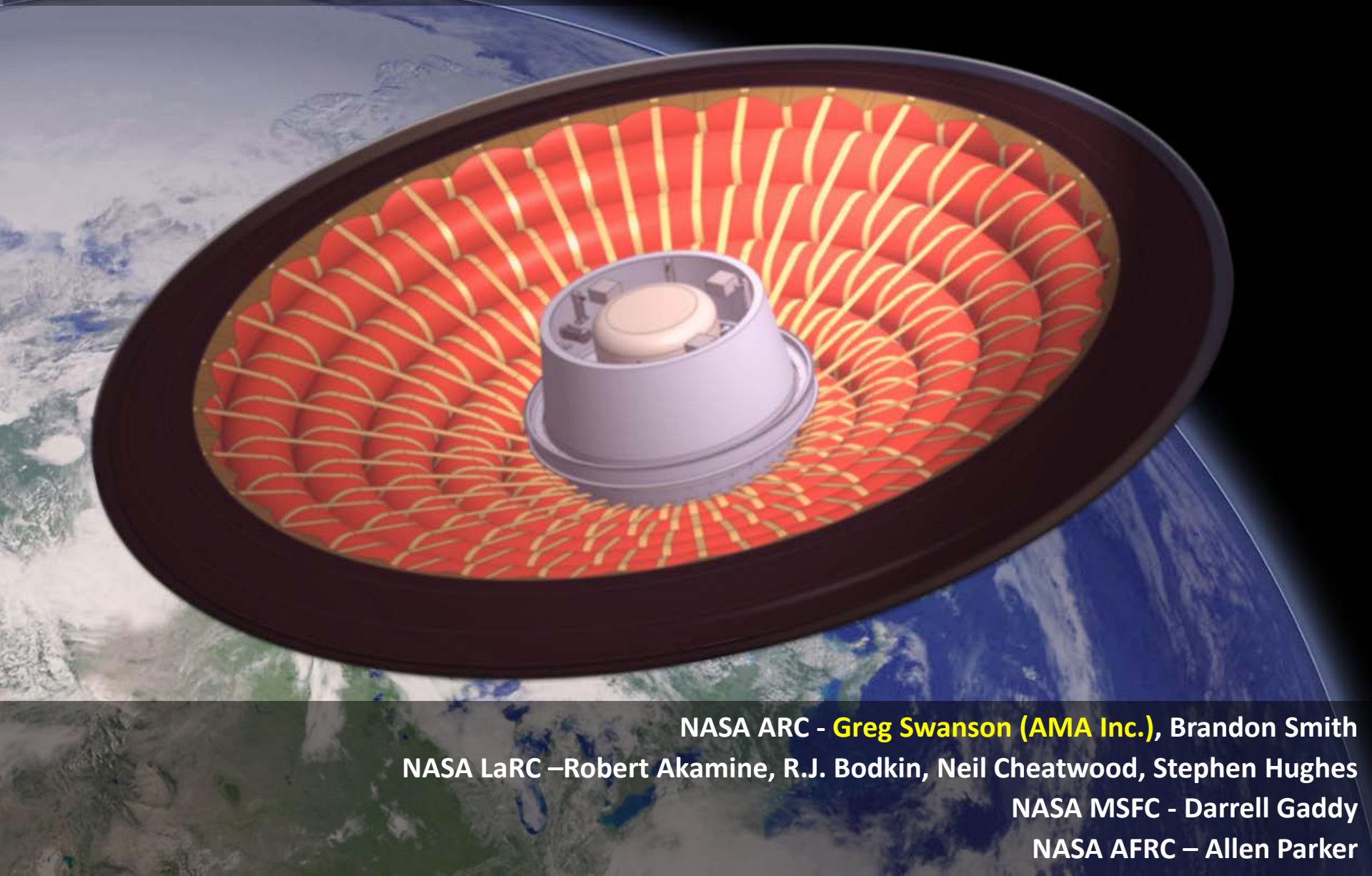
The HIAD Orbital Flight Demonstration Instrumentation Suite

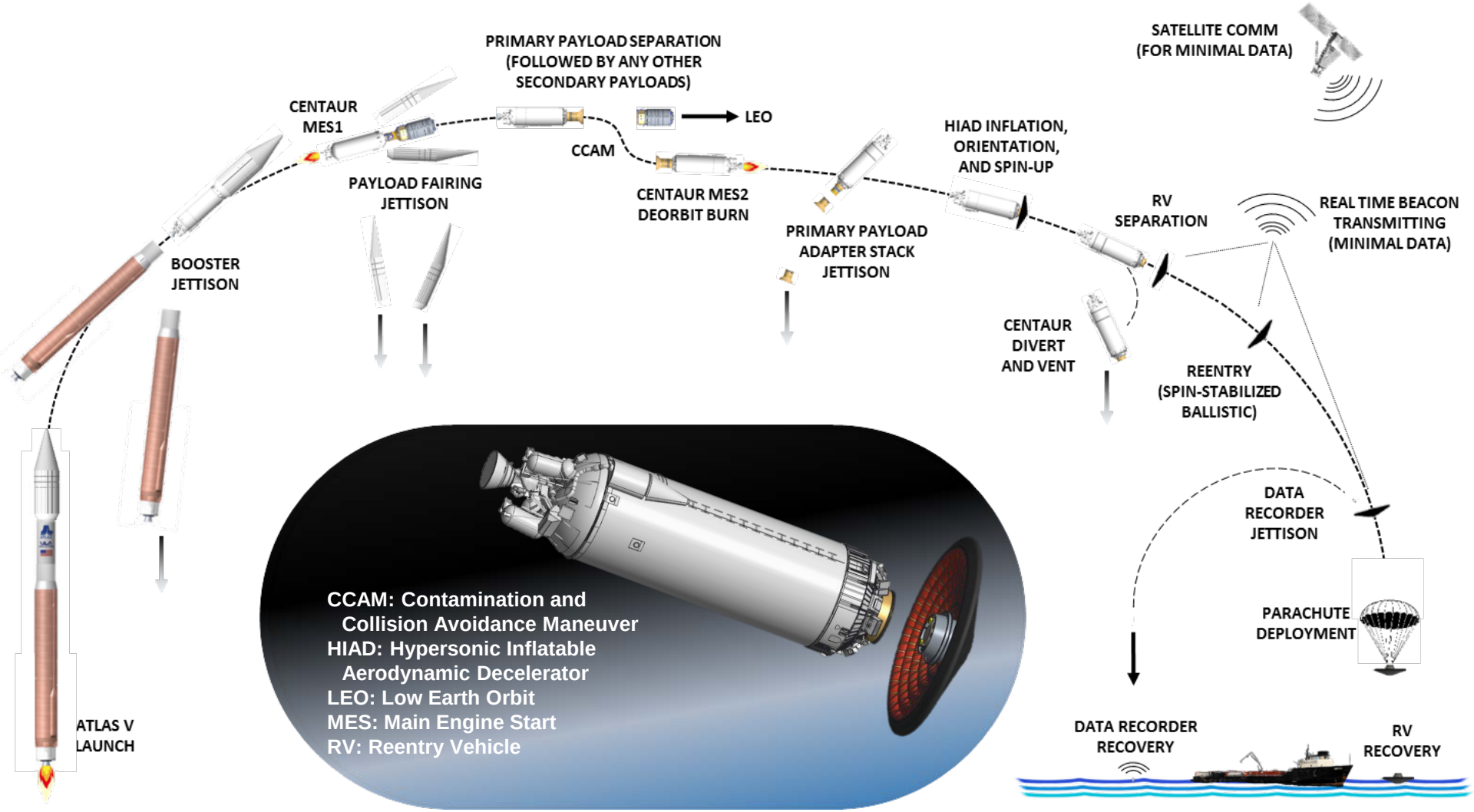
National Aeronautics and Space Administration



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 – 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

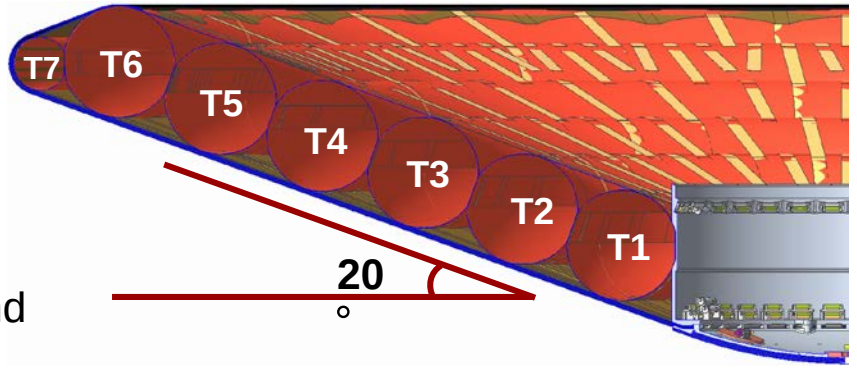
- IRVE-3 Flight Tested the Gen-1 Inflatable Structure, and Gen-1 F-TPS
  - Gen-1 Inflatable Structure Capability: 250° C
  - Gen-1 F-TPS Capability: 35 W/cm^2
- LOFTID will Flight Test the Gen-2 Inflatable Structure and Gen-2 F-TPS
  - Gen-2 Inflatable Structure Capability: 400° C
  - Gen-2 F-TPS Capability: 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)

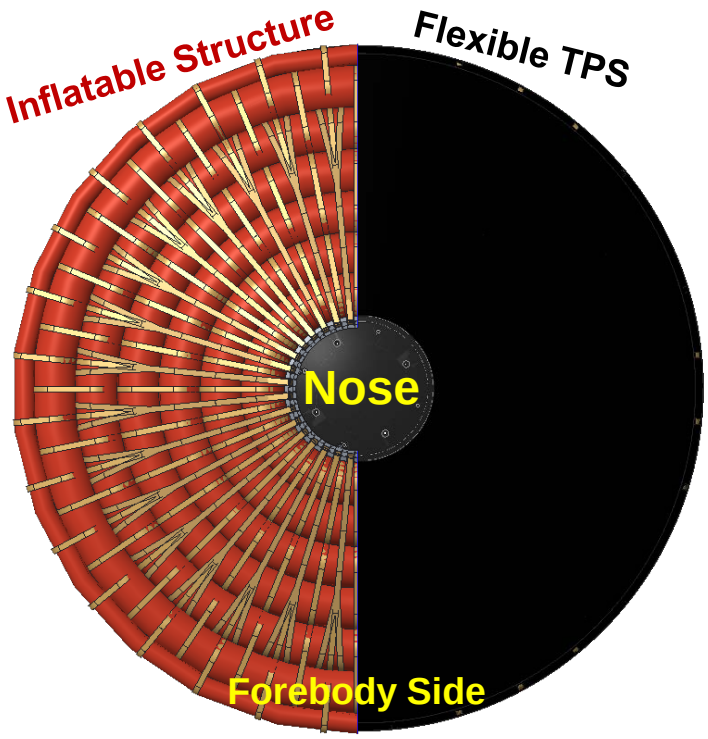
	IRVE-3	LOFTID	LEO Return	ISS Down Mass	ULA Engine Recovery	Humans to Mars
Diameter (m)	3	6	<6	8-12	12	18.8
Forebody Geometry (deg)	60	70	60-70	60-70	60-70	70
Entry Mass (kg)	330	1700	<1500	<5000	12000	56000
Entry Velocity (km/s)	2.7	7.1	7-7.5	7-7.5	4-6.5	6.2
Peak Heat Rate (W/cm2)	15	60	<50	30-40	<30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

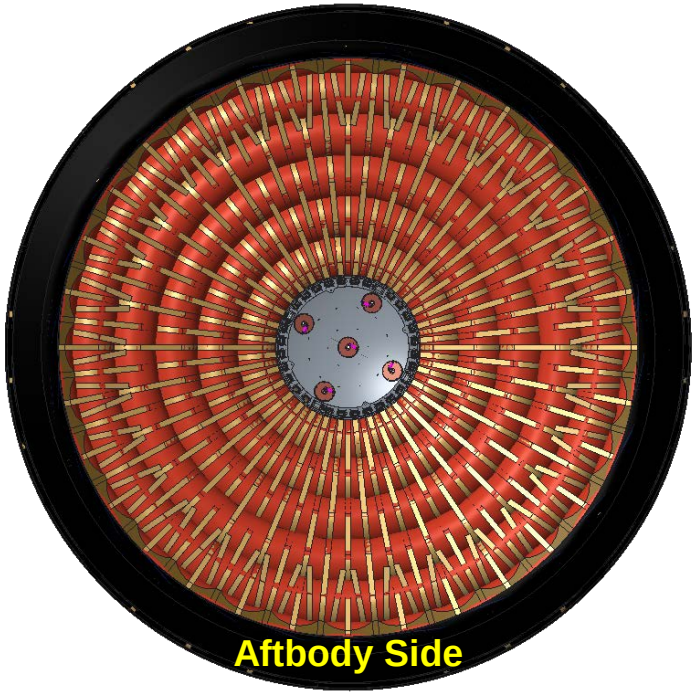
Aeroshell Design

6m HIAD Aeroshell

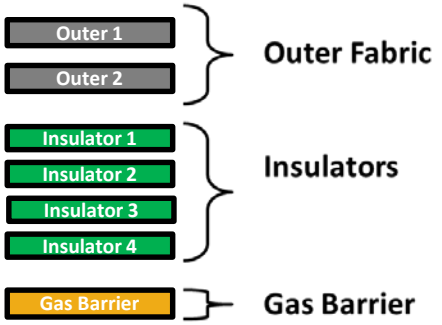
- Stacked torus inflatable structure
- Flexible TPS (F-TPS)
- 70-deg half-angle sphere-cone
- 6 structural tori, 1 shoulder torus
- Tori are formed by structural cords and bound together by high strength straps
- 4 (x32) centerbody attachment points



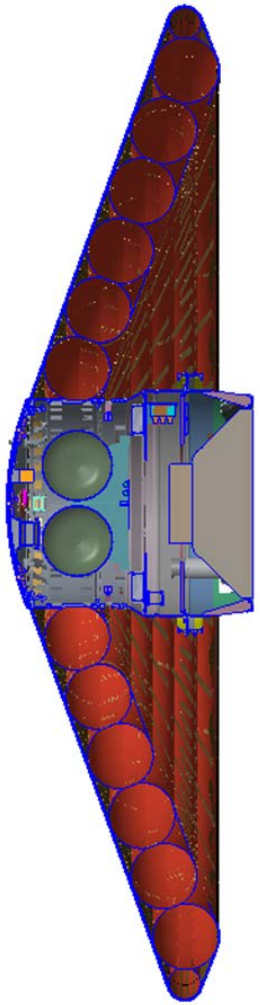




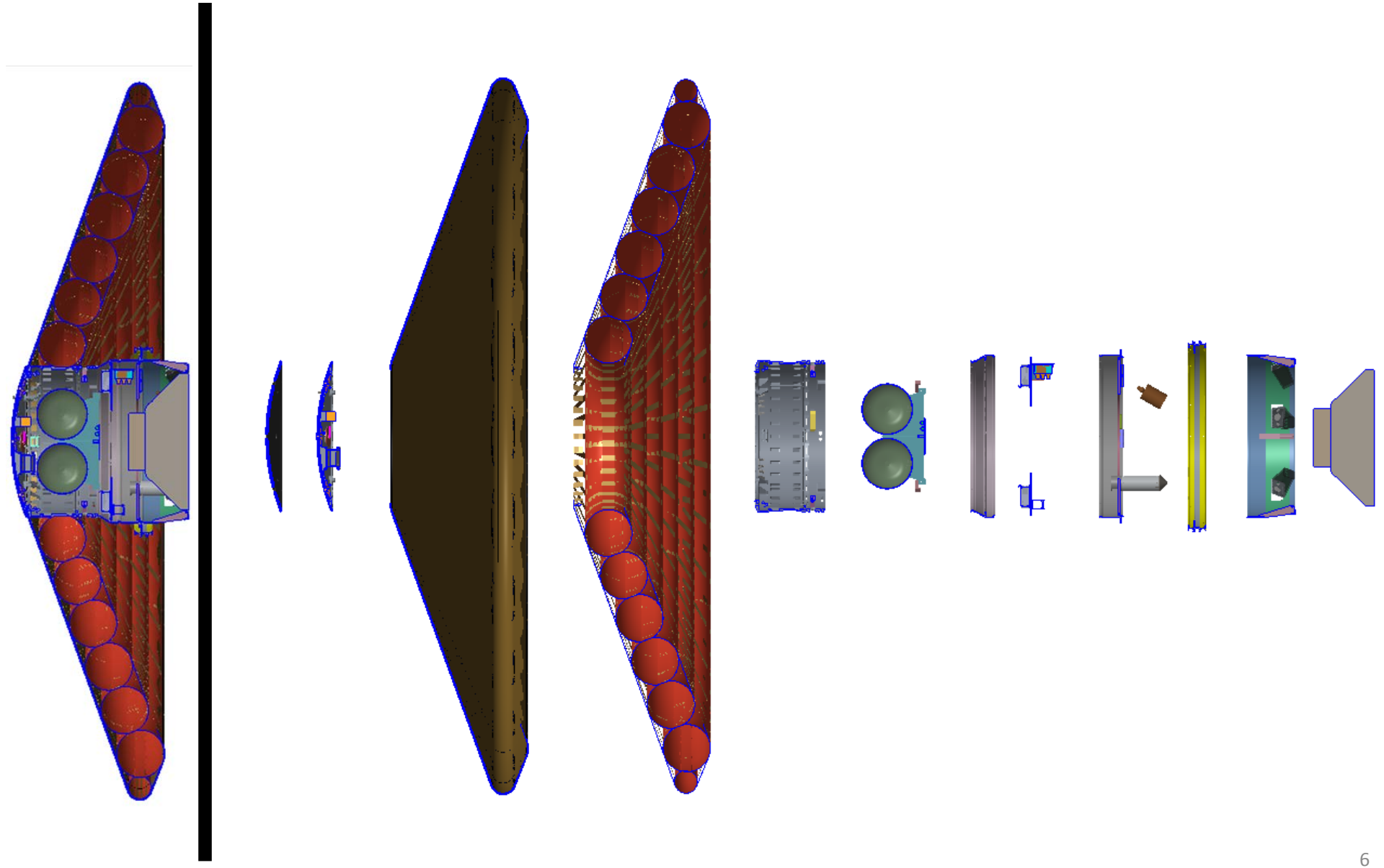
Flexible TPS Design



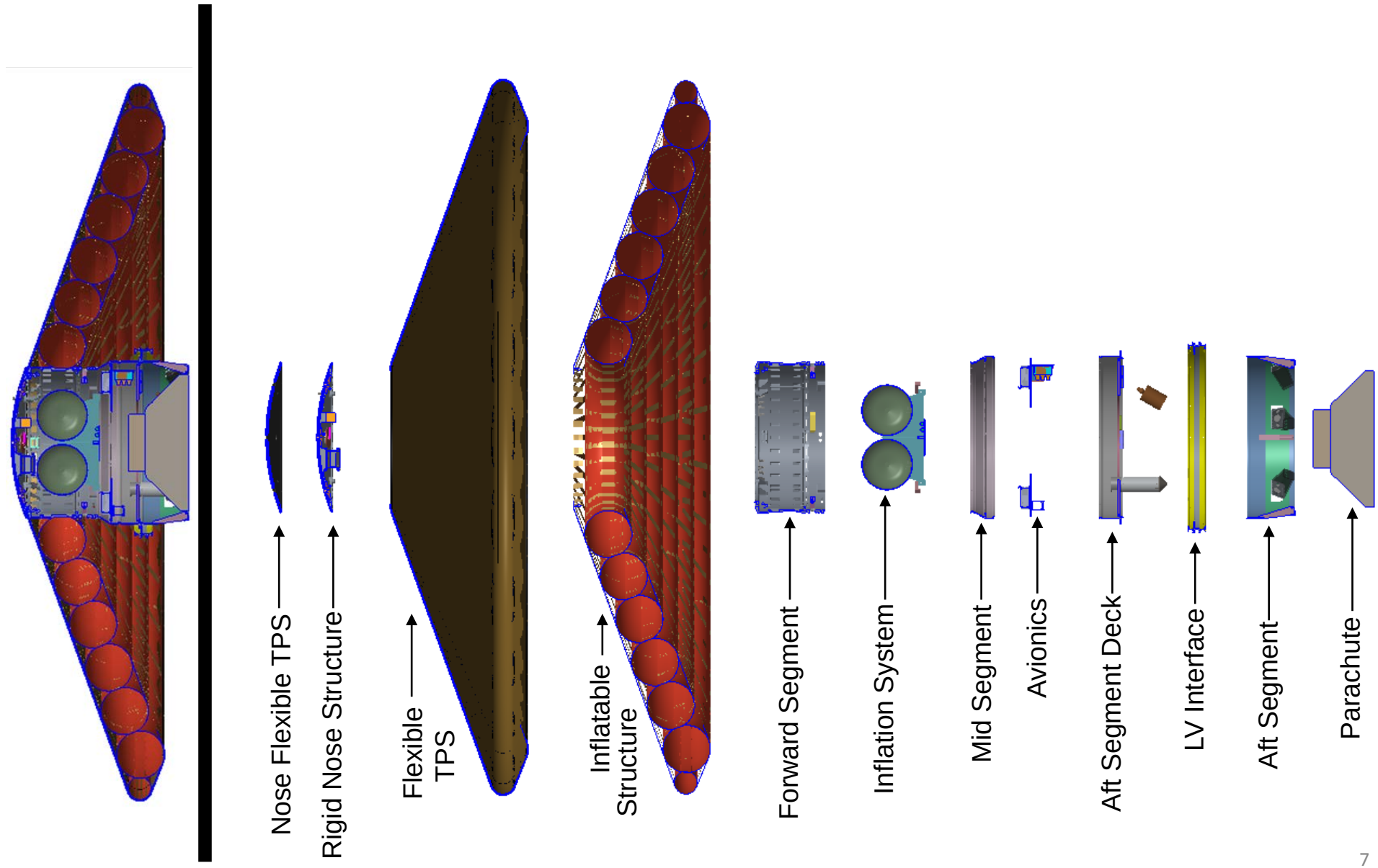
RV Instrumentation Overview



RV Instrumentation Overview



RV Instrumentation Overview



RV Instrumentation Overview

Nose Flexible TPS

Rigid Nose Structure

Thermocouples (TCs),
Fiber Optic Sensor

Heat Flux Gages,
Radiometer,
Pressure Transducers

Flexible
TPS

TCs

Inflatable
Structure

TCs

Forward Segment

Loadcell Clevis Pins

Inflation System

Pressure Transducers,
Flow Rate Sensor,
Hot Film Anemometers

Mid Segment

Avionics

IMU, GPS

Aft Segment Deck

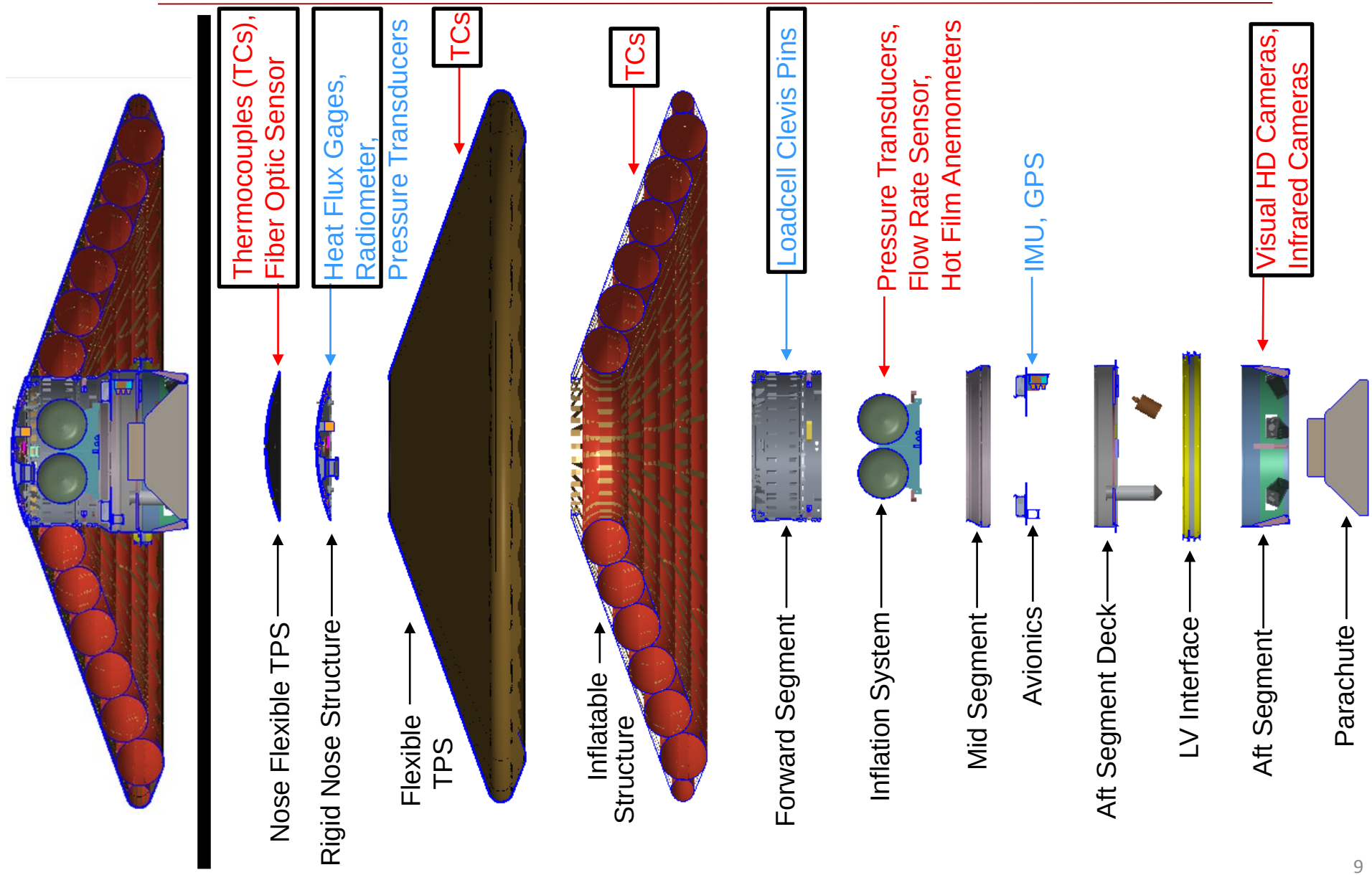
LV Interface

Aft Segment

Visual HD Cameras,
Infrared Cameras

Parachute

RV Instrumentation Overview

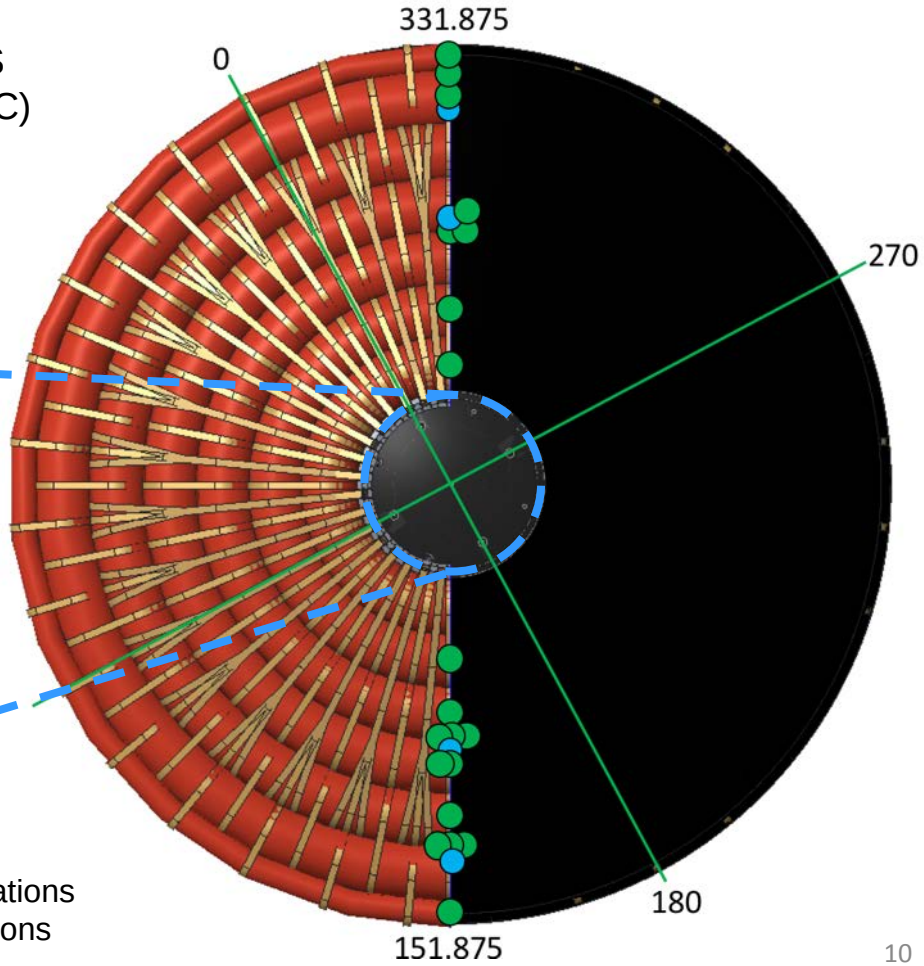


Forebody Thermocouples

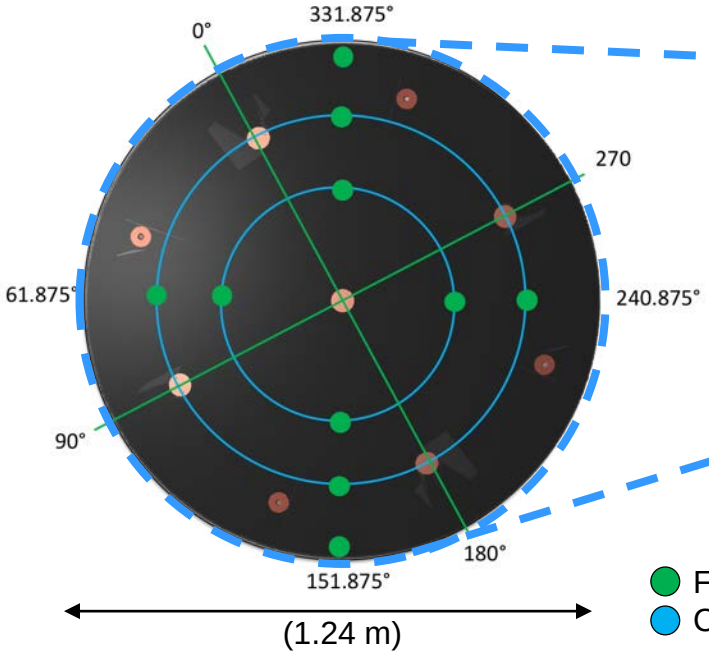
- 22 Nose Thermocouples (TCs)
  - Measurement: In-depth thermal response at location of peak heating
  - 10 Type R TCs, 12 Type K TCs
  - Leveraging Arc Jet and IVRE-3 heritage
- 36 Flank Flexible-TPS (F-TPS) TCs
  - Measurement: In-depth thermal response of TPS covering inflatable structure (limit of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

(spin stabilized at 2-4 rpm)

Forebody Layout



Rigid Nose Layout

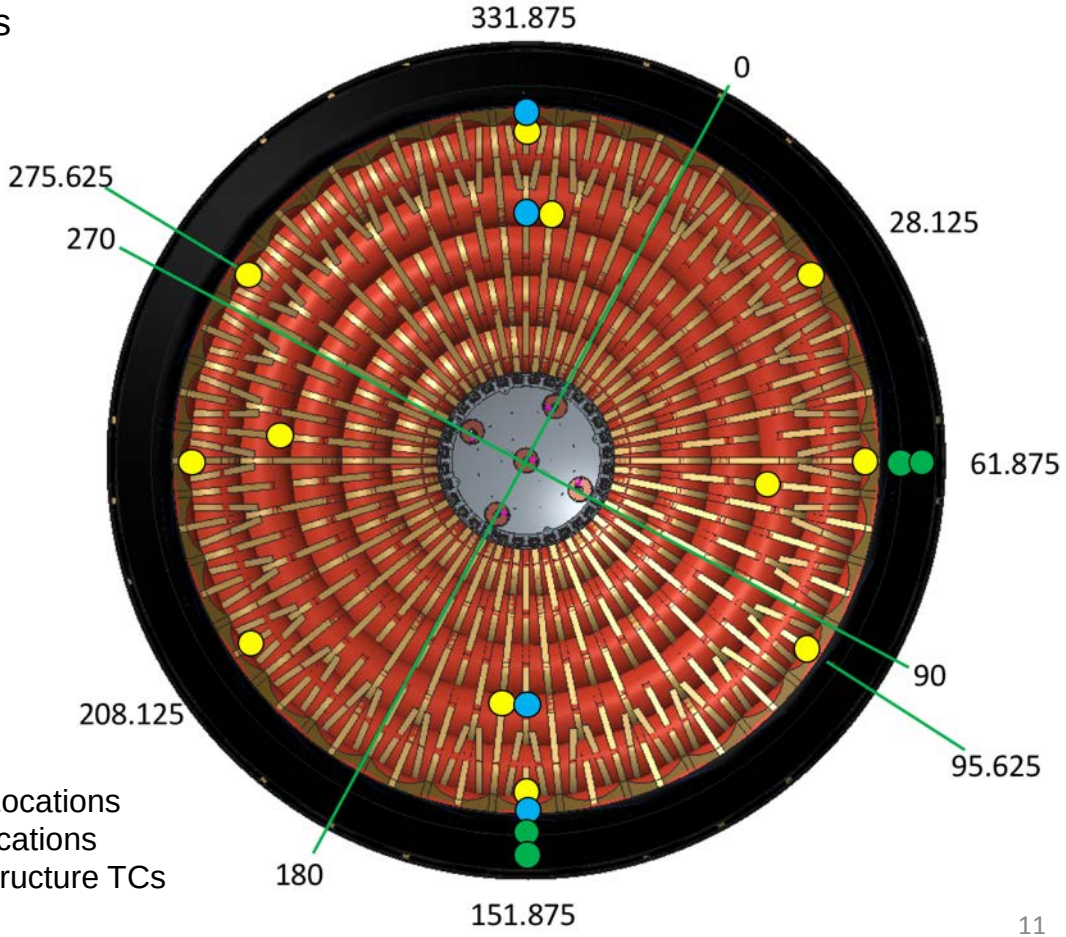


Aftbody Thermocouples

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

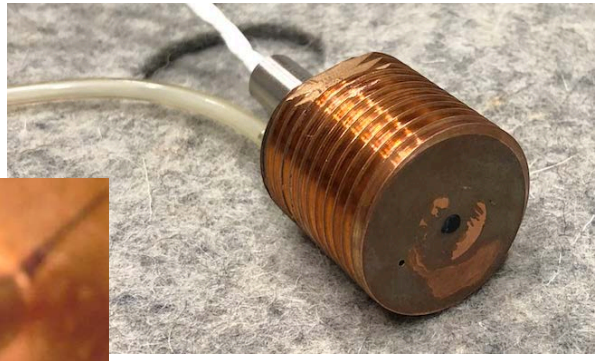
TC Embedded in Structural Cord

Aftbody Layout

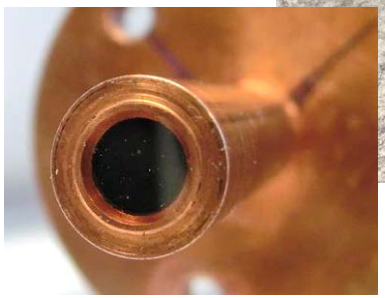


Heat Flux Sensors

- 4 Total Heat Flux Sensors
  - Measurement: Measure heat rate 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

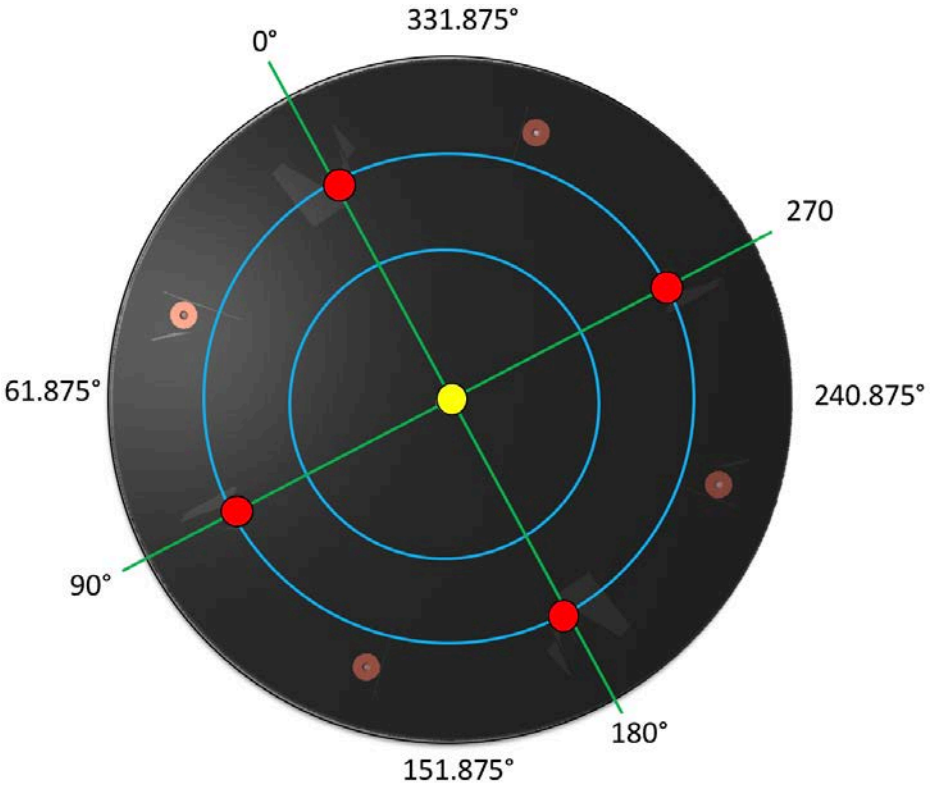


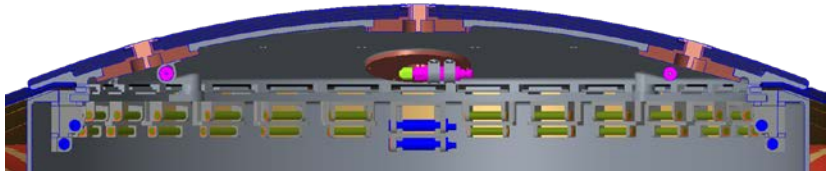
IRVE3 Heat Flux Gage



MEDLI2 Radiometer

Rigid Nose Layout

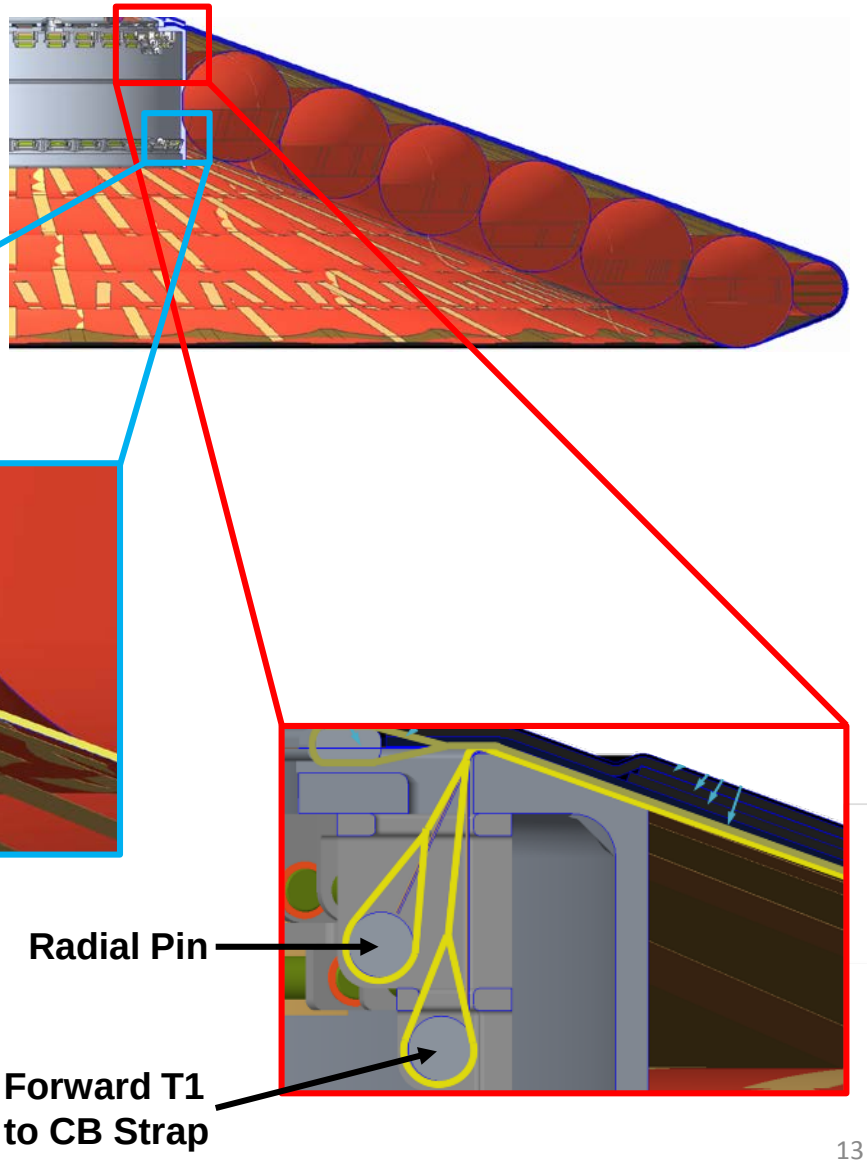




Cross-Section of Nose

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



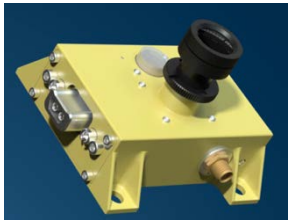
Loadcell Clevis Pin

Cameras

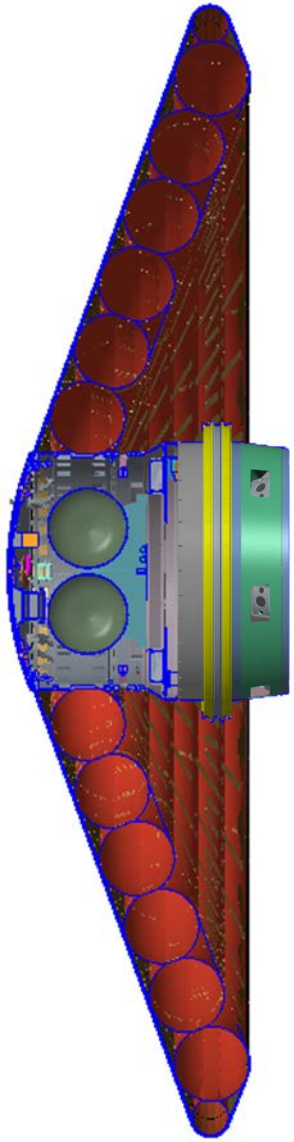
- 6 Visual HD Cameras
  - Aeroshell deflection and observation (360° Coverage)
- 1 Up-Look camera
  - Launch vehicle separation and parachute deployment
- 12 Infrared Cameras
  - Aft-body temperature distribution (360° Coverage)

IR Camera

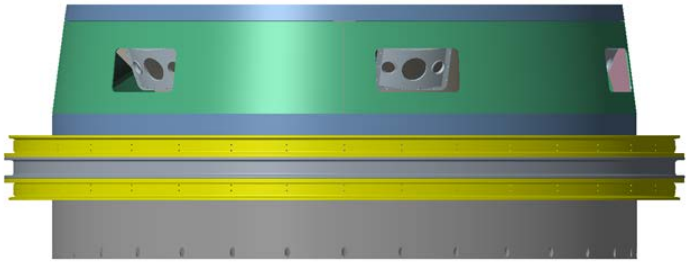
HD Aeroshell Camera



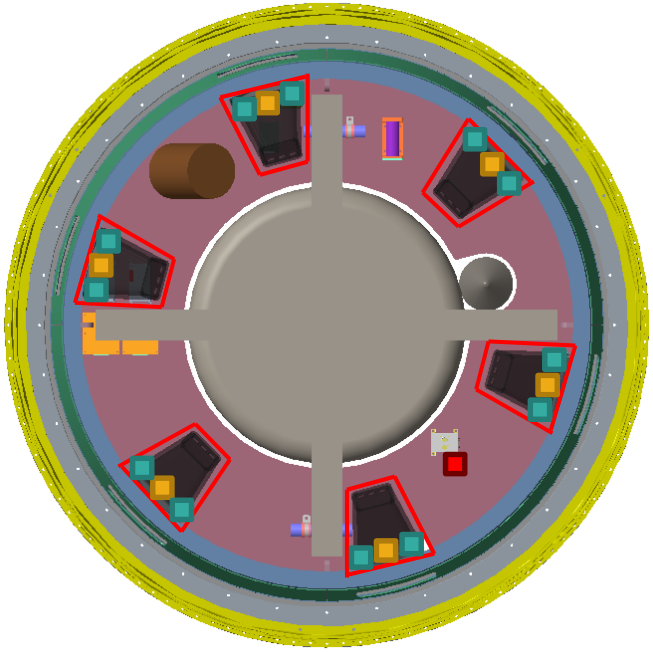
HD Up-Look Camera



Aft Deck Camera Mounting



6 Camera Pod Locations

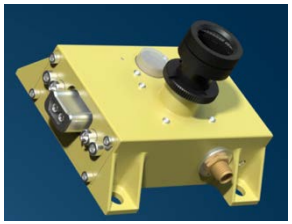


Cameras

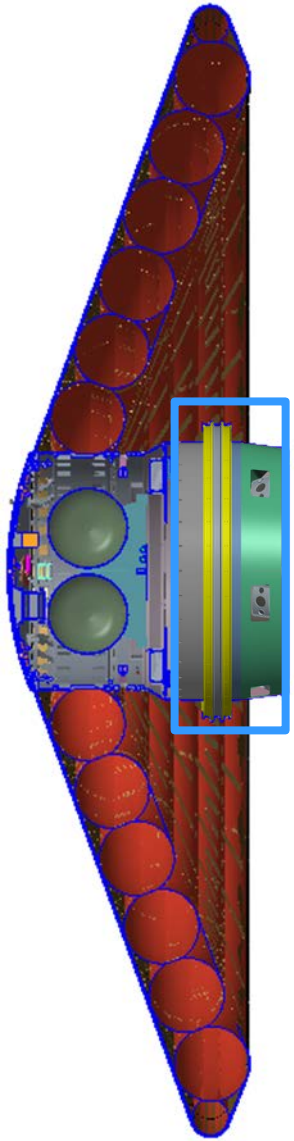
- 6 Visual HD Cameras
  - Aeroshell deflection and observation (360° Coverage)
- 1 Up-Look camera
  - Launch vehicle separation and parachute deployment
- 12 Infrared Cameras
  - Aft-body temperature distribution (360° Coverage)

IR Camera

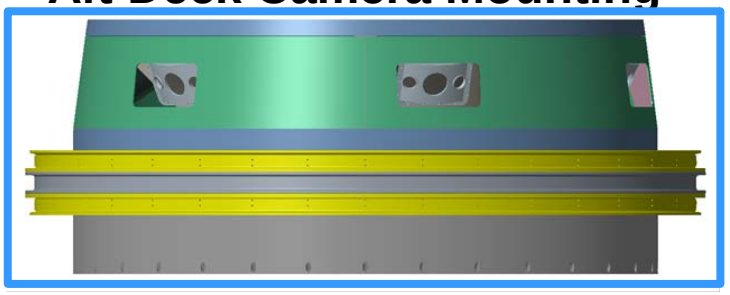
HD Aeroshell Camera



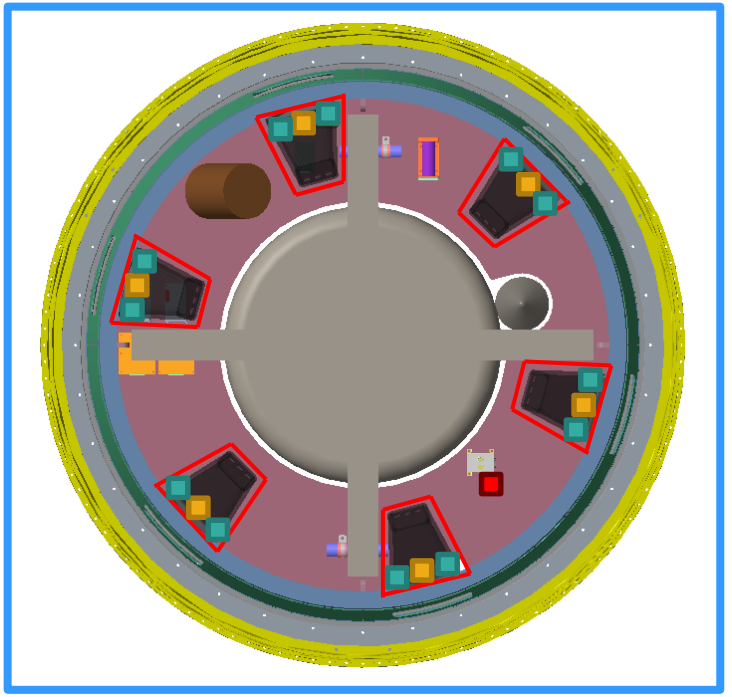
HD Up-Look Camera



Aft Deck Camera Mounting



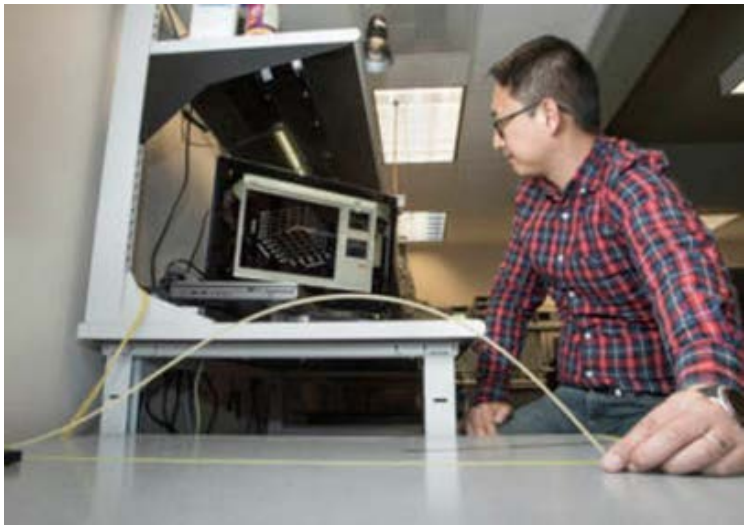
6 Camera Pod Locations



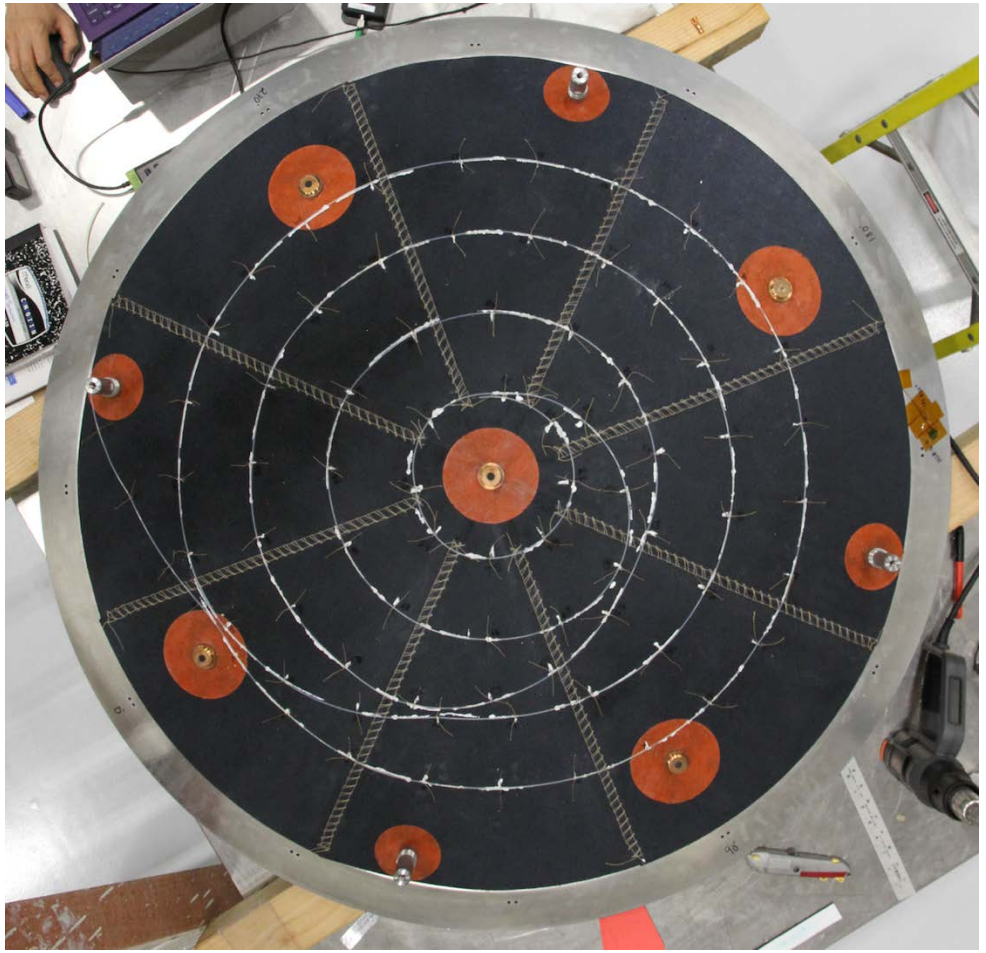
Developmental Instrumentation

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



Fiber Optic Strain Sensing Fiber in Lab



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

Questions?