The HIAD Orbital Flight Demonstration Instrumentation Suite

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LOFTID Mission

LeO Flight Test of an Inflatable Decelerator (LOFTID)

CCAM: Contamination and Collision Avoidance Maneuver
HIAD: Hypersonic Inflatable Aerodynamic Decelerator
LEO: Low Earth Orbit
MES: Main Engine Start
RV: Reentry Vehicle
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/cm²

- 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/cm²

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)

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

- Nose Flexible TPS
- Rigid Nose Structure
- Flexible TPS
- Inflatable Structure
- Forward Segment
- Inflation System
- Mid Segment
- Avionics
- Aft Segment Deck
- LV Interface
- Aft Segment
- Parachute
RV Instrumentation Overview

- Thermocouples (TCs), Fiber Optic Sensor
- Heat Flux Gages, Radiometer, Pressure Transducers
- Loadcell Clevis Pins
- Pressure Transducers, Flow Rate Sensor, Hot Film Anemometers
- IMU, GPS
- Visual HD Cameras, Infrared Cameras
- Nose Flexible TPS
- Rigid Nose Structure
- Flexible TPS
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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 ~400°C)
  - All Type K TCs at various F-TPS depths
  - Heritage on IRVE-3

(spin stabilized at 2-4 rpm)
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 Image]
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
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
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)

Aft Deck Camera Mounting

6 Camera Pod Locations
Cameras

- **6 Visual HD Cameras**
  - Aeroshell deflection and observation (360° Coverage)
- **1 Up-Look camera**
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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?