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>
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<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

Flexible TPS Design

- Outer Fabric
- Insulators
- Gas Barrier
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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- Forward Segment
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Structure:
- 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
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
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

![TC Embedded in Structural Cord Image]

Aftbody Layout

![Aftbody Layout Diagram]

- **F-TPS TC Locations**
- **Cord TC Locations**
- **Inflatable Structure TCs**
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](image)

![MEDLI2 Radiometer](image)

![Rigid Nose Layout](image)
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)

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**Aft Deck Camera Mounting**

**6 Camera Pod Locations**

**IR Camera**

**HD Aeroshell Camera**

**HD Up-Look Camera**
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
Questions?