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

Flexible TPS Design
- Outer Fabric
- Insulators
- Gas Barrier
RV Instrumentation Overview
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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

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

Loadcell Clevis Pins, Pressure Transducers, Flow Rate Sensor, Hot Film Anemometers, IMU, GPS, Visual HD Cameras, Infrared Cameras
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

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**Forebody Layout**

**Rigid Nose Layout**

- F-TPS TC Locations
- Cord TC Locations

*(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*

![Diagram showing Aftbody Layout with TC Locations]

- **Aftbody Layout**
  - 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

MEDLI2 Radiometer

IRVE3 Heat Flux Gage

Rigid Nose Layout

Cross-Section of Nose
• **12 Strap Loadcell Clevis Pins**
  • Measurement: Total load reacted at each cardinal position ($0^\circ$, $90^\circ$, $180^\circ$, $270^\circ$)
  • 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
  - 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?