Planned Orbital Flight Test of a 6m HIAD

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Why Inflatables?

- Entry mass at Mars, and other destinations with atmospheres, is limited by entry capsule drag.
- Hypersonic Inflatable Aerodynamic Decelerator (HIAD) approach:
  - Stows aeroshell in compact volume for launch.
  - Deploys aeroshell to larger diameter before atmospheric interface.
  - Allows payload to use the full cylinder of launch fairing (HIAD can stow forward of payload).
  - Delivers more payload mass and/or to higher altitudes.
  - Reduces peak heat flux by decelerating earlier, in less dense upper reaches of the atmosphere.

Example Mars entry at 6km/s, 2200kg entry mass (MSL-class).

<table>
<thead>
<tr>
<th>Diameter (m)</th>
<th>Heat Rate (W/cm²)</th>
<th>Altitude (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.57</td>
<td>50</td>
<td>200</td>
</tr>
<tr>
<td>15.0</td>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td>15.0</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>4.57</td>
<td>80</td>
<td>50</td>
</tr>
</tbody>
</table>

Example graph showing heat rate and altitude vs. Mach number.
HIAD Development

- **Ground Test**: Project to Advance Inflatable Decelerators for Atmospheric Entry (PAI-DAE): Soft goods materials R&D
- **Flight Test**: Inflatable Reentry Vehicle Experiment (IRVE), 2007: Launch vehicle anomaly – no experiment
- **Flight Test**: IRVE-II, 2009: IRVE “build-to-print” re-flight of 3m HIAD, fully successful; demonstrated in-flight inflation, ability to maintain pressure, and aerodynamic stability (hypersonic through subsonic flight)
- **Ground Test**: HIAD Project: Improved structural and thermal system performance (Gen-1 & Gen-2); extensive work on entire aeroshell
- **Flight Test**: IRVE-3, 2012: Improved (Gen-2) 3m diam structure & F-TPS, higher energy reentry (20G’s, 15W/cm²), first HIAD controlled lift entry, L/D moved 0.2 to -0.2 by CG offset
- **Ground Test**: HIAD-2 Project: Improving on Gen-2 F-TPS, evaluating advanced structures, packing of 6m HIAD, and manufacturability at scales >10m

- **Next flight test**: Scaling up flight vehicle to 6m diameter, with higher energy orbital trajectory. This presentation will give an overview of the updated flight test plans.
Next Flight Test: Reentry from Orbit

- Will demonstrate HIAD technology at scale and entry conditions relevant to Earth return and Mars mission infusion opportunities, for NASA heavy down-mass missions and commercial applications.

- This mission has appeared before at IPPW
  - In 2016, as HULA, a proposed HIAD flight test with United Launch Alliance (ULA); interested in using HIADs for first stage engine recovery.
  - In 2017, as HIAD-TDM, under NASA’s Space Technology Mission Directorate (STMD), Technology Demonstration Missions (TDM).

- Funded by TDM as “LeO Flight Test of an Inflatable Decelerator” (LOFTID)
- Started 10/1/17 on a 39-month schedule, planning launch in late 2020 as a secondary payload on an Atlas V; not assigned to a specific launch manifest.

**Mass Breakdown**
- 62 kg (136 lb) inflatable structure
- 106 kg (233 lb) FTPS & sensors
- 140 kg (310 lb) inflation system
- 462 kg (1020 lb) centerbody
- 130 kg (290 lb) parachute system
- 290 kg (640 lb) avionics & sensors
- 1190 kg (2630 lb) total
LOFTID Con-Ops

LOFTID: LeO Flight Test of an Inflatable Decelerator
CCAM: Contamination and Collision Avoidance Maneuver
HIAD: Hypersonic Inflatable Aerodynamic Decelerator
LEO: Low Earth Orbit
MES: Main Engine Start
RV: Reentry Vehicle
Ground Track, & Separation Detail

- Primary Payload Released
- Payload Adapter Jettisoned
- LOFTID Aeroshell Inflated
- LOFTID Reentry Vehicle Released
Flight Test Description

- Ballistic coefficient of 25 kg/m² (6m diam, ~1200 kg)
- 12G entry, peak flux on nose of 35-50 W/cm²
- 6m inflatable structure ground test unit previously tested to higher loads (50,000 lbs pressure load, ~19G’s), and at AoA in 80x40 National Full-scale Aerodynamics Complex (NFAC) at NASA Ames
- F-TPS coupons arc-jet tested to ~2x LOFTID’s peak flux

LOFTID flight will:

- Expose full vehicle to time-varying flight environment, with in-flight deployment and flight inflation system
- Apply thermal & structural load to full vehicle during same test
- Provide aerothermal response data for flight heat pulse, with long enough duration to allow in-depth performance evaluation of F-TPS
- Measure aft-side aerothermal response
Project Team

- NASA Langley: Design and analysis of reentry vehicle, trajectory, inflation system, & most of avionics; assembly, integration, & testing
  - Airborne Systems: Inflatable structure
  - Jackson Bond Enterprises: Flexible TPS
- ULA: Integration to launch vehicle; recovery parachute & recovery ship
- NASA Marshall: Data acquisition system, cameras
- NASA Ames: Aeroshell fabrication oversight, flight sensors
- NASA Kennedy / Launch Services Program: Fiber Optic Sensor System (FOSS)
Status / Future Schedule

- Authority to Proceed: October 2017
- System Requirements Review: May 10-11, 2018
- Currently fabricating engineering development units of centerbody, inflatable structure, & F-TPS based on ground-tested designs; will load test & hard pack multiple times
- Preliminary Design Review: November 2018
- Critical Design Review: May 2019
- Ground testing ends with Complete System Test – autonomous deployment and inflation of reentry vehicle in LaRC vacuum chamber: January 2020
- RV repacked & ready to ship to launch site: July 2020
- 4 months schedule reserve before start integration to launch vehicle
- LOFTID HIAD will be largest diameter blunt body reentry ever flown

Apollo: 3.9m  
Orion: 5.0m  
LOFTID: 6.0m
Questions?
Inner Three Tori for a 12m HIAD

- 0.6m (24’’)
- 77 kg (170 lb)
- 8.4m (27.6’)

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