HIAD Developments

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1 September 2026

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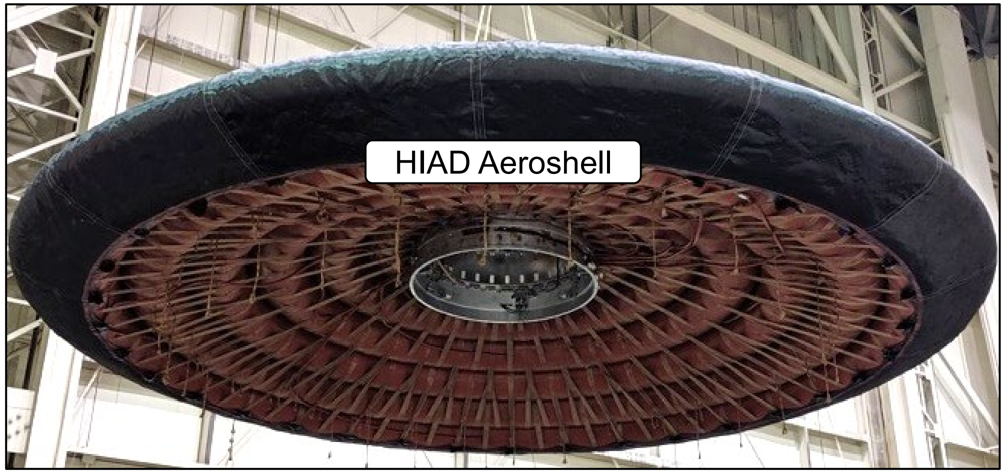
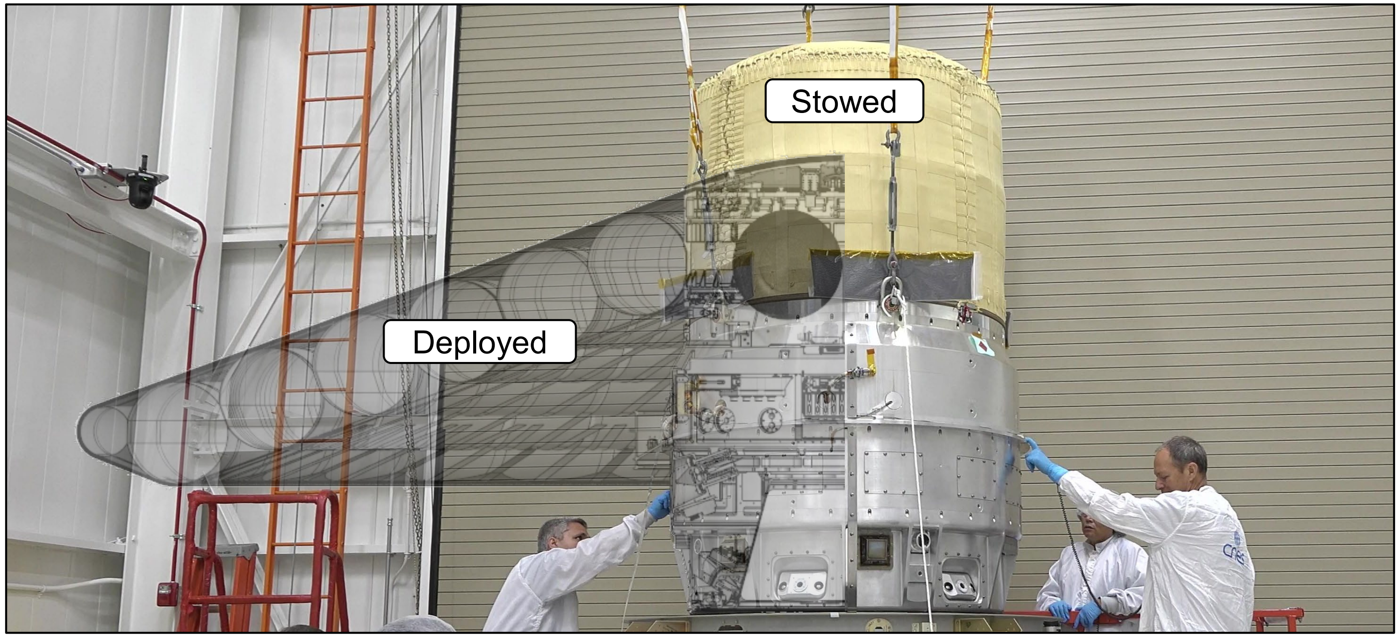
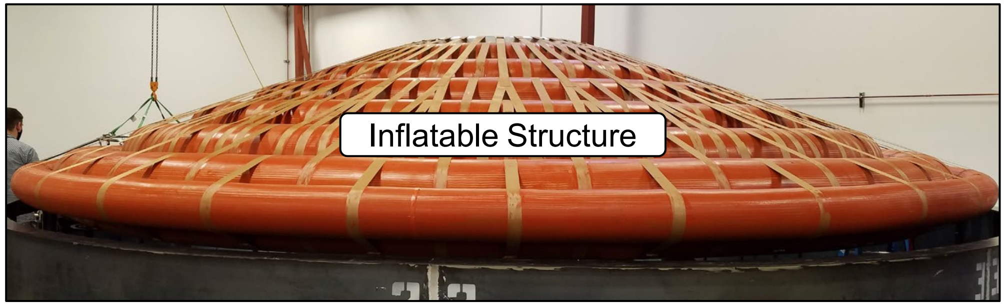
What is a HIAD?

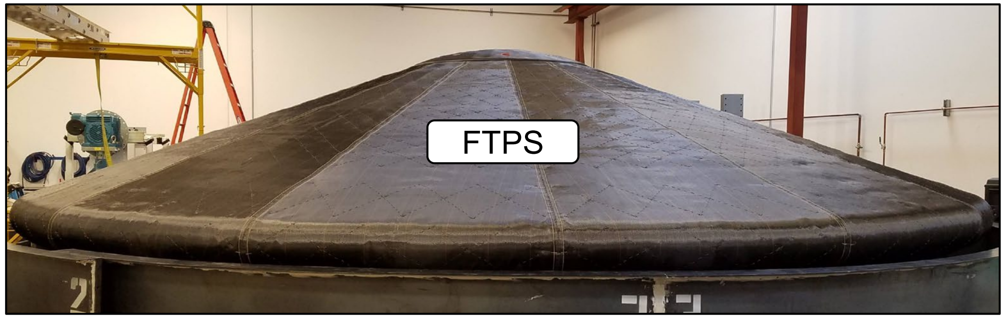
Hypersonic Inflatable Aerodynamic Decelerator (HIAD) is a deployable aeroshell technology consisting of two main constituents that can be hard-packed into a small volume:

- **Inflatable Structure** that is heat resistant and sufficiently rigid to maintain shape against aerodynamic forces
- **Flexible Thermal Protection System (FTPS)** that shields the Inflatable Structure and payload from the shear and extreme heating of atmospheric entry





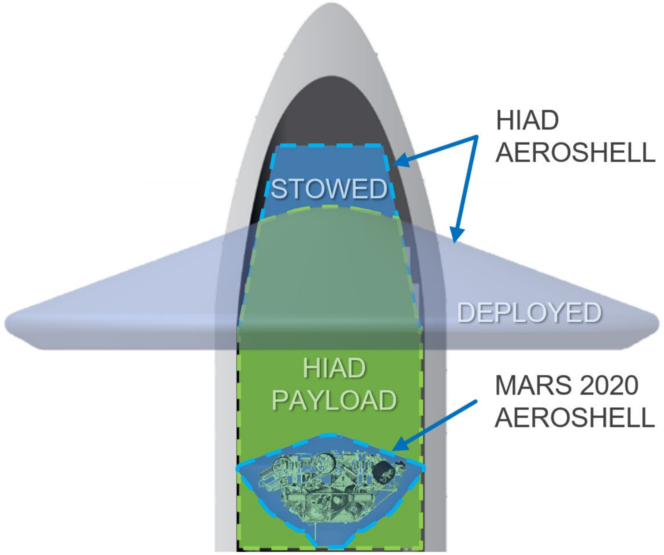




Why is HIAD Technology Useful?

- **Answers a challenge the world has been working to overcome since the mid-1960’s**
- **Compacts to a small launch configuration, providing more usable launch volume for the payload and/or spacecraft**
- **Decelerates efficiently in the less dense upper reaches of the atmosphere, enabling access to higher elevations**
- **Requires no backshell, allowing more mass for payload and convenient access to the payload**
- **Lightweight structure is very stiff and responds efficiently to loads like conventional rigid structure**
- **Scalable to accommodate diverse reentry mass and trajectory requirements**
- **Stable across all speed regimes through hypersonic, supersonic, transonic, and even subsonic flight**

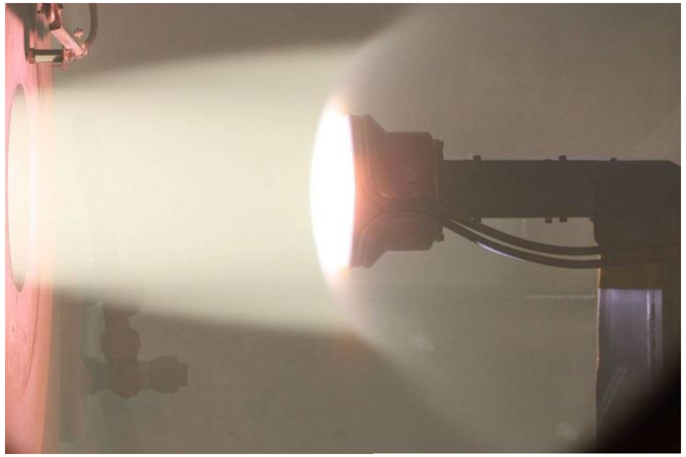
A **Hypersonic Inflatable Aerodynamic Decelerator** (HIAD) can be stowed in a compact volume for launch and cruise, then deployed prior to entry to decelerate payloads at destinations with atmospheres.

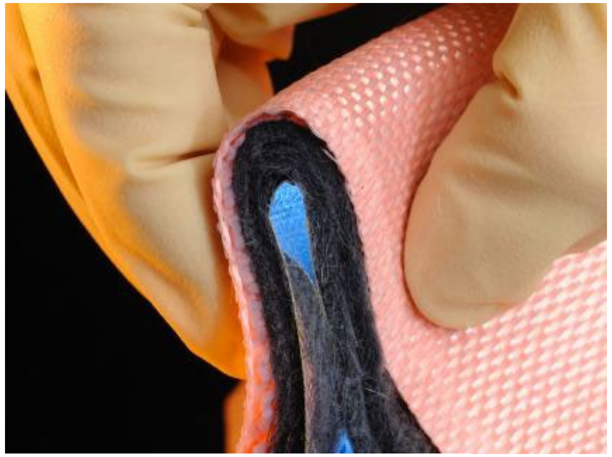


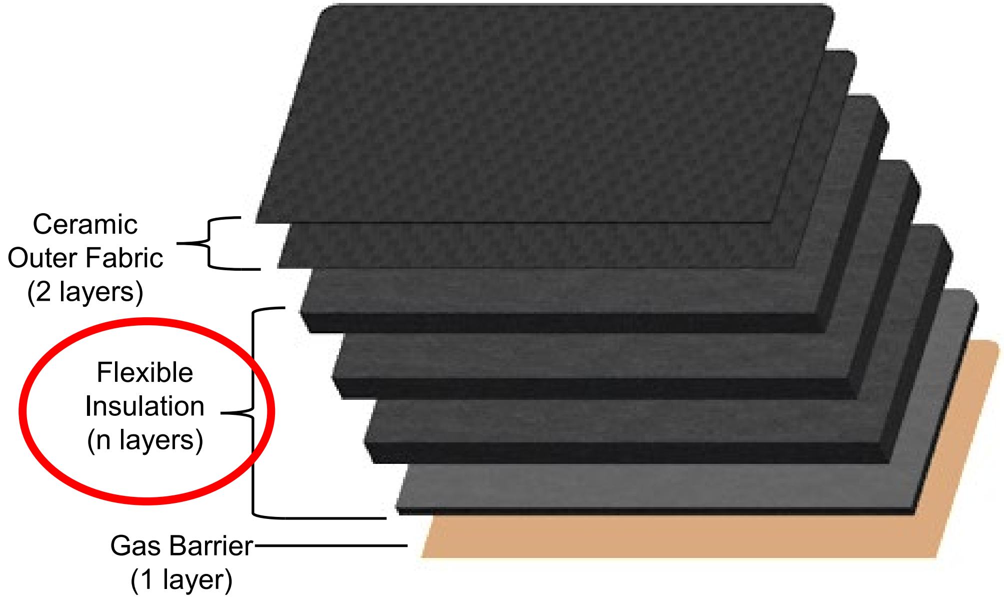
Larger aeroshells enable much more entry mass (not limited by launch fairing size)

Why are We Here?

- **The FTPS has ceramic outer fabric layers, flexible insulation layers, and a structural gas barrier layer**
- **The high-performance thermal insulation requires**
  - Manufacturability at scale
  - Durability for assembly, ground testing, hard packing, launch environments, and deployment
  - Flight performance after everything above
- **HIAD designers are interested in the manufacturing and high-fidelity analysis of fibrous insulation materials**

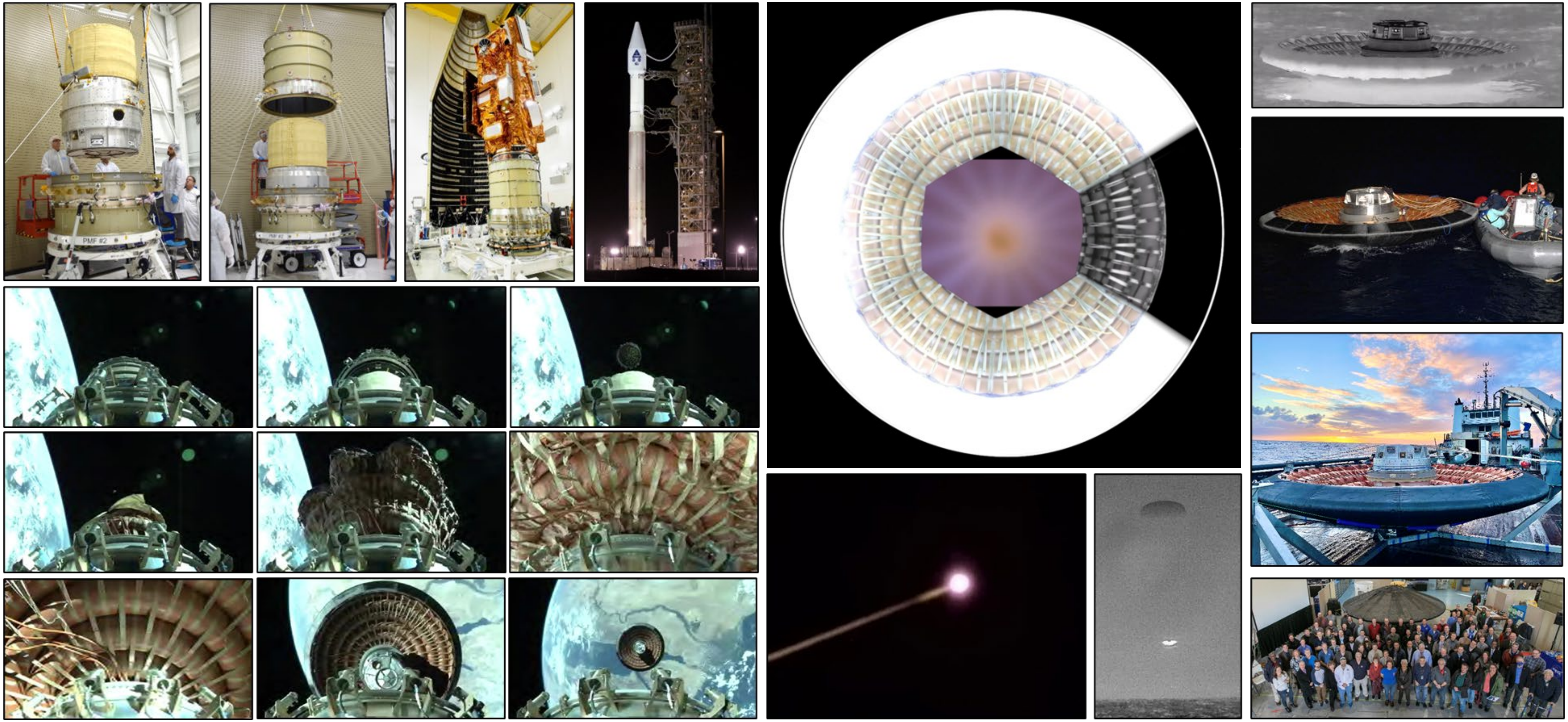






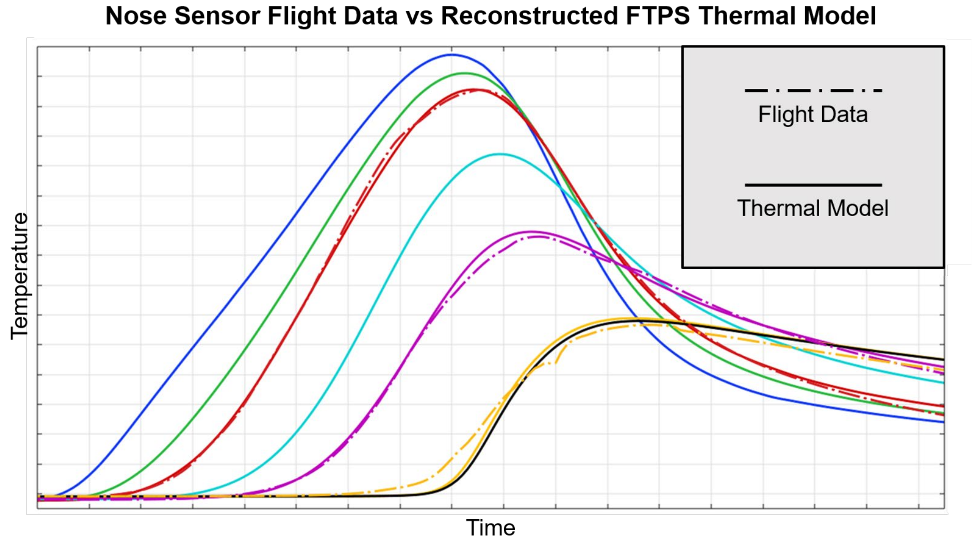
LOFTID in Pictures

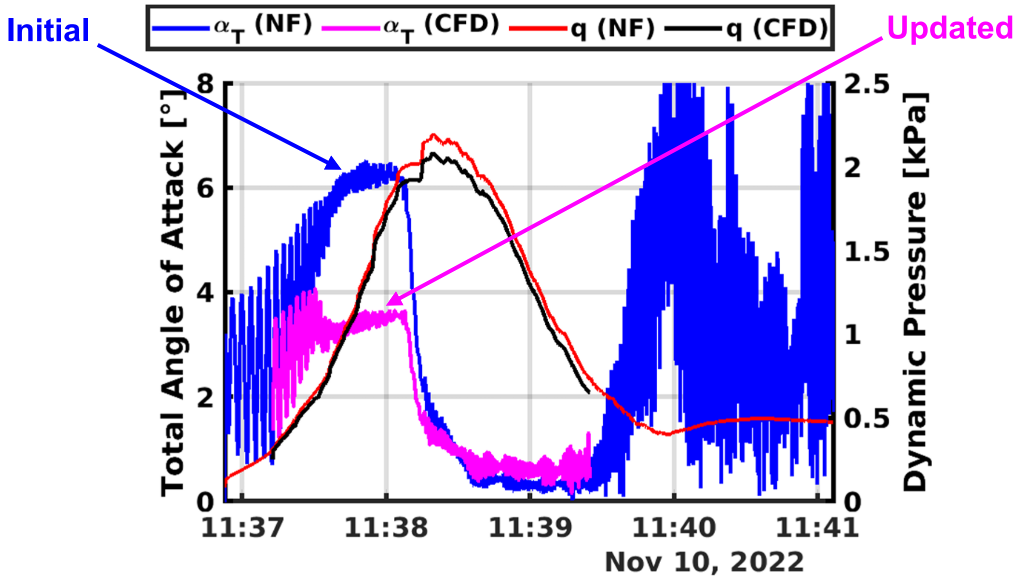
Low-Earth Orbit Flight Test of an Inflatable Decelerator



LOFTID Quick Results Summary

- First successful inflatable aeroshell from orbit
- Largest blunt body to enter the atmosphere
- Uncontrolled but stable flight throughout hypersonic, supersonic, transonic, and subsonic flight regimes
- Passively decelerated from 18,000mph (5 miles per second) down to less than 80mph before deploying its parachute for splashdown
- Excellent thermal, structural, aerodynamic, flight mechanics, and aeroheating model correlations
- Highly stable with minor trim AoA prior to peak dynamic pressure
  - Note: IMU data was not recorded due to a network timeout error
  - Initial look using nose pressure measurements and Newtonian flow modeling indicated a roughly 6.5 deg total AoA
  - Deeper analysis using more applicable CFD calibrated pressure modeling indicated a roughly 3.6 deg total AoA





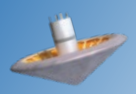
HIAD Capabilities

Technology Readiness Level (TRL): HIAD maturity is dependent on the application

- High TRL for <6 m unguided entry at Earth
- High TRL for ~2000 kg entry mass
- Mid TRL for >8 m aeroshells
- Mid-Low TRL for >8 km/s entries (e.g. lunar return)
- Low TRL for guided/controllable HIAD
- Low TRL for cool gas generator (CGG) inflation system

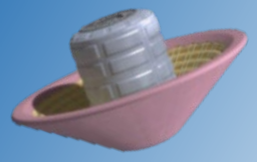
High TRL (unguided)

In Development



HIAD LEO SmallSat

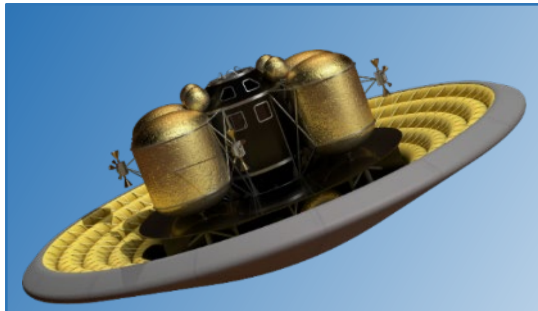
Robotic Missions



Terrestrial Down Mass

Launch Vehicle Asset Recovery

(applicable to heavy down mass from orbit)



High Mass Delivery at High Altitudes at Mars

(including humans to Mars)

	HIAD LEO SmallSat	Robotic Missions	Terrestrial Down Mass	Launch Vehicle Asset Recovery	High Mass Delivery at High Altitudes at Mars
Entry Mass (lbm)	< 1,500 lbm	< 3,500 lbm	> 12,000 lbm	> 50,000 lbm	> 80,000 lbm
Entry Mass (kg)	< 700 kg	< 1,600 kg	> 5,400 kg	> 22,000 kg	> 36,000 kg
Diameter (m)	~ 3m	< 6 m	10-12 m	10-18 m	16-20 m

Image Credit: ULA

HIAD Advancements Since LOFTID

Characteristic	VERA Scale-up Factor Compared to LOFTID
Aeroshell Diameter	1.7
Torus Minor Diameter	1.9
Strap Attachments	3.8
Entry Mass	21
Drag Load	30
Internal Pressure	2.3
Inflatable Volume	6.5

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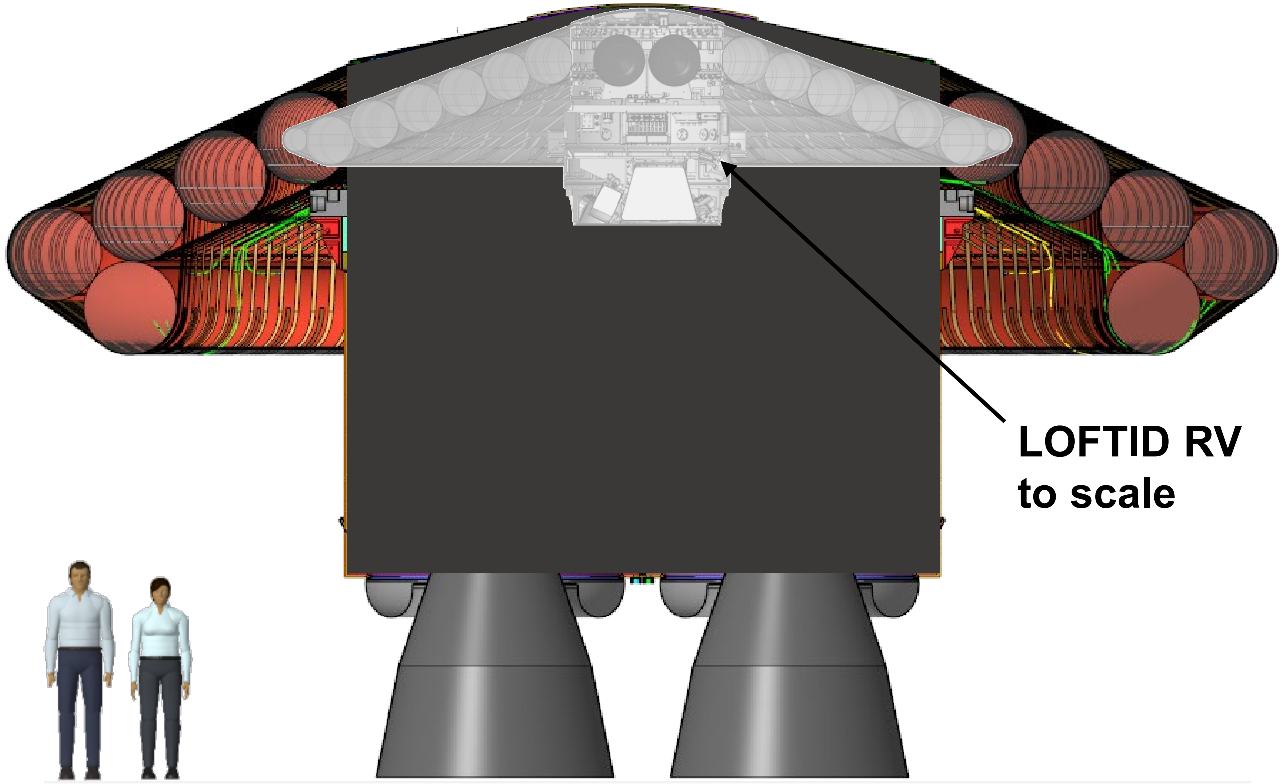
Vulcan Engine Recovery Aeroshell (VERA)
Overall Diameter 10.4 m (34 ft)

The LOFTID Reentry Vehicle (RV) overall diameter of 6.0m is less than the outer diameter of the first torus for VERA



HIAD technology has extended capacity and scale since the LOFTID flight demonstration.

Commercialization: HIAD LEO SmallSat Module

- **NASA is adapting the HIAD to support smaller companies who want reentry capability**
- **The intent is to develop a single simple design that fits a wide range of SmallSat needs**
    - Simple bolt-on interface with one electrical connector
    - Withstand a range of LEO entry velocities, FPAs, and masses
- **Proposing that NASA absorb the upfront costs that can be prohibitive for small companies**
    - Non-recurring engineering "one size fits most" design, development, analysis, fabrication fixtures, test fixtures, and ground qualification testing
    - Allows companies to purchase only a module itself
- **Module includes the stowed HIAD aeroshell, centerbody, nose, inflation system, minimal avionics, and minimal instrumentation**

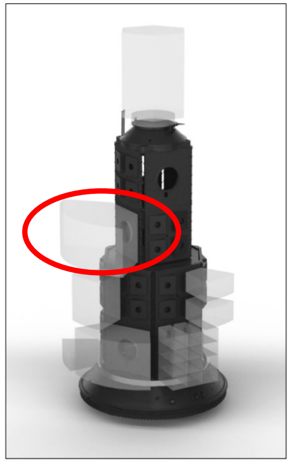


Figure 1-1: Example Mission Configuration using Rideshare Plates

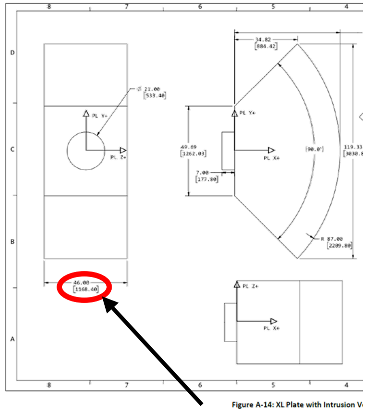
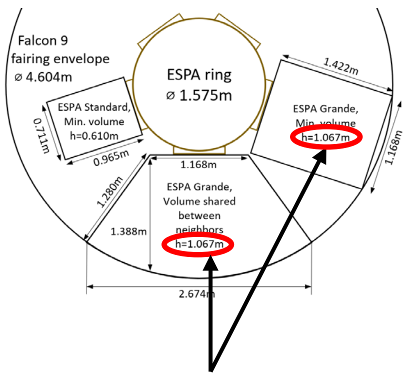


Figure A-14: XL Plate with Intrusion V

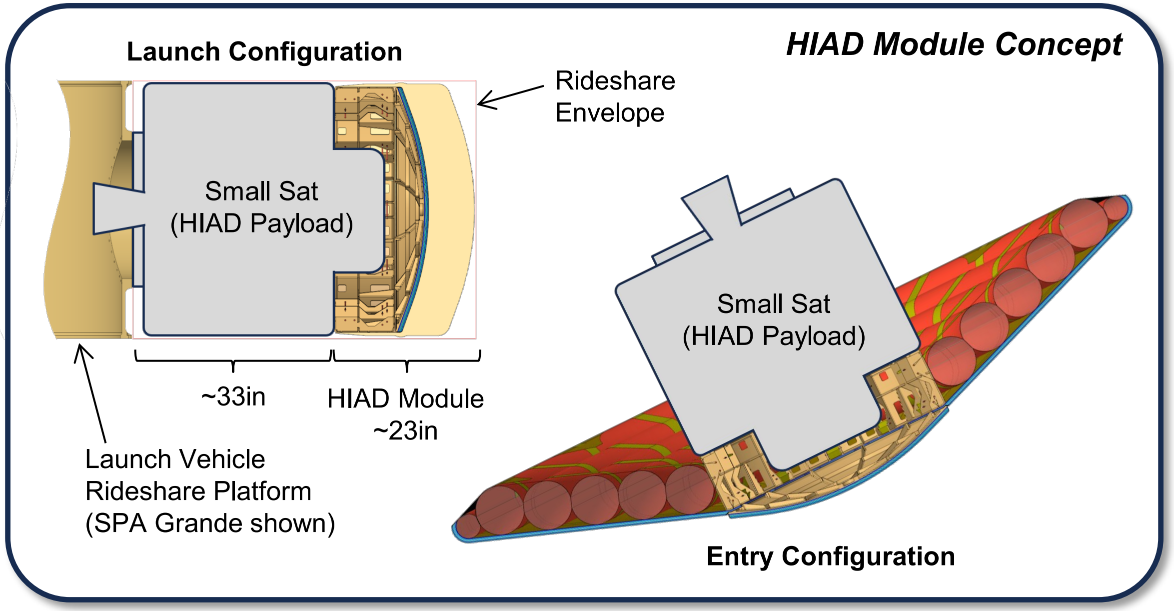
Falcon XL Plate limiting OML dia. dimension is 46.00in (1.168m)



SPA Grande Limiting OML dia. dimension is 42.00in (1.067m)

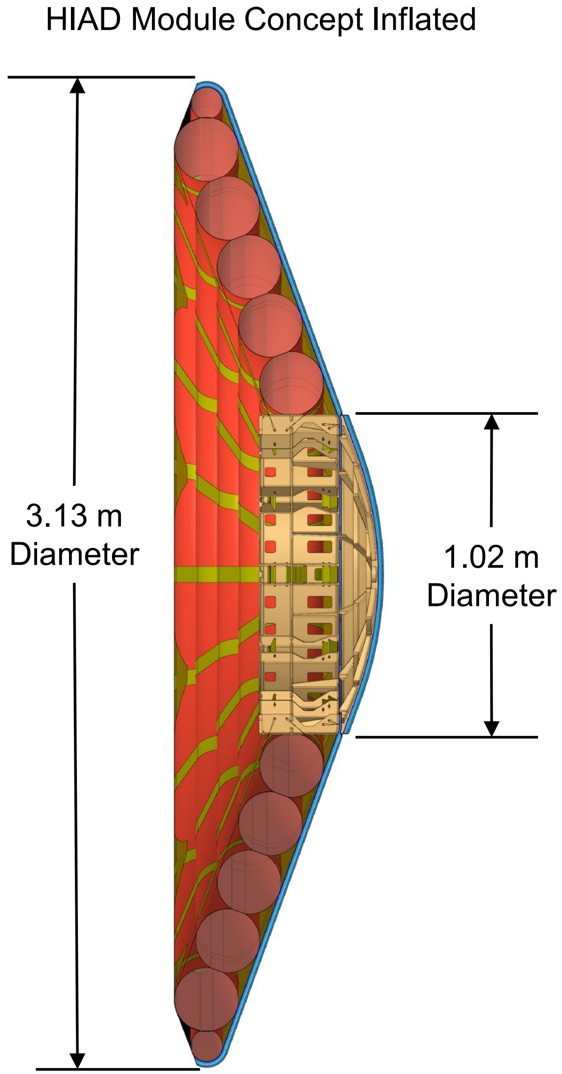
Excerpted from Rideshare User Guides

Use stowed dia. of 42.0in for rideshare compatibility

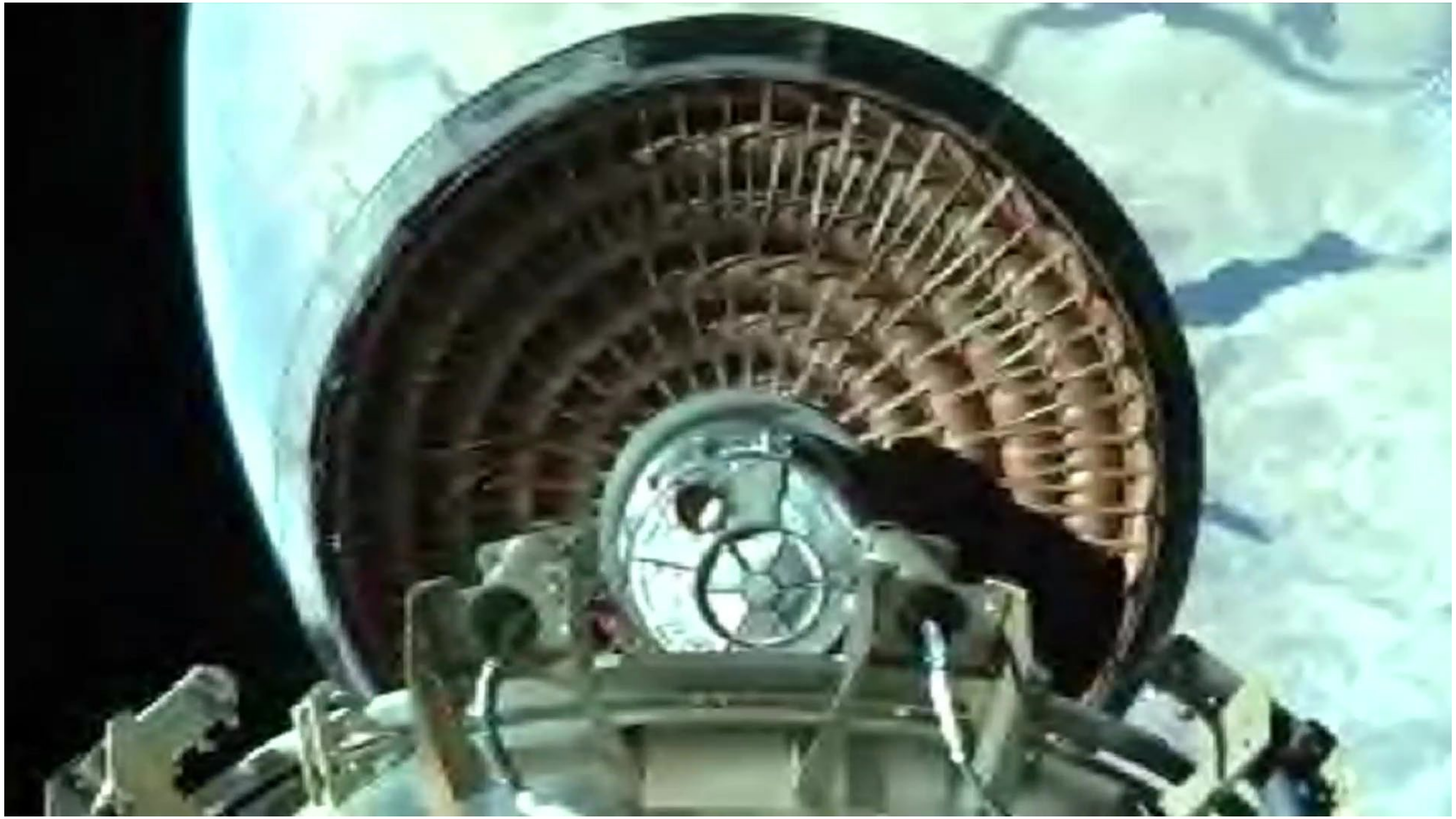


Proposed Near-Term HIAD Development

- **Near-term Development Roadmap**
  - **Phase 1 - Commercial Low Earth Orbit Ballistic Return** - Deliver a qualified reentry module to commercial providers
  - **Phase 2 - Guided Earth Return** - Add precision landing capability for commercial and government missions
  - **Phase 3 - Lunar Return** - Extend the same architecture to lunar payload return velocities, EFPAs, and masses
- **Phase 1 HIAD Module provides platform for NASA and/or partner incremental flight tests**
  - Test materials, steering capability, cascade decelerator, retro-propulsion transition, etc.
  - Optional instrumentation can augment standard package
  - Rocket Lab's Hypersonic Accelerator Suborbital Test Electron (HASTE) may be suitable for scale and relevant velocities (7.5 km/s) in tests from Wallops Flight Facility
- **Propose returning an ISS module as a large demo of HIAD capability requiring less up-mass than a dedicated payload**

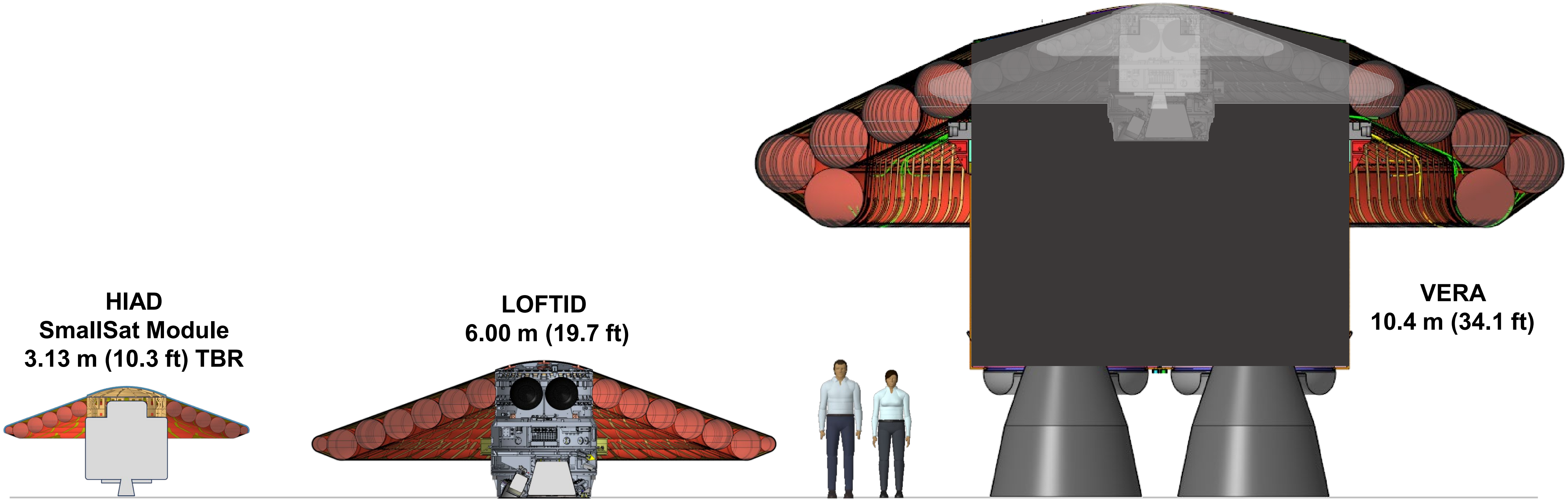


Questions?



BACKUP

Relative Scale



HIAD Module: Current Assumptions/Ground Rules

- **Create a standard spacecraft module for reentry**
  - Standardized centerbody, nose cap, cone angle, torus stack, FTPS, inflation system, and restraint release system, plus an optional instrumentation package and data acquisition
  - Payload interface is a bolt circle, a connector, and a volume keep out zone
- **Target small sat secondary payloads in SPA Ring/XL Plate class**
  - Standardized secondary payload interfaces enable affordable rideshares and establish payload sizing constraints for a wide range of small business applications
  - Recent history of small business interest in HIAD at this scale
- **Assume the reentry mass can be as high as the limit mass of the payload launch interface, or as high as separation system limitations allow**
- **Payload responsible for power, GPS, IMU, reentry start command, deorbit function, attitude at atmospheric interface, and parachute**