Small Satellite-sized Hypersonic Inflatable Aerodynamic Decelerators (HIAD) for Interplanetary Science Missions

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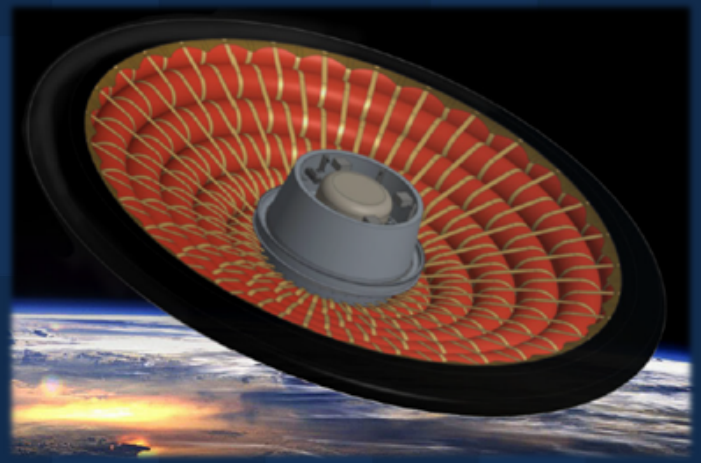
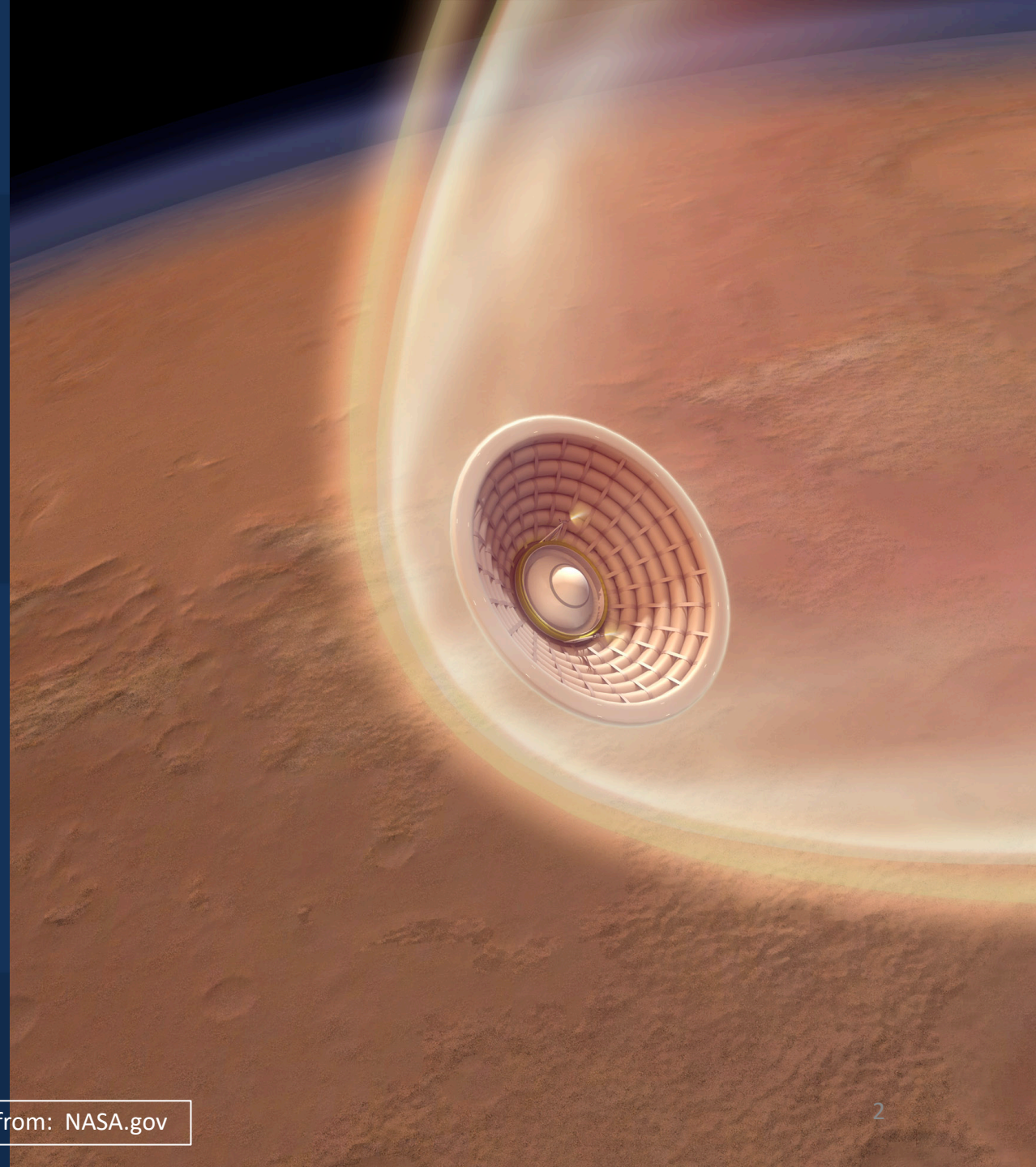
Overview

- Motivation for Satellite-sized HIADs
- Feasibility study
  - Two limiting cases
  - Design sensitivities
- Payload capacity exploration (Earth)
- Conclusions and Discussion



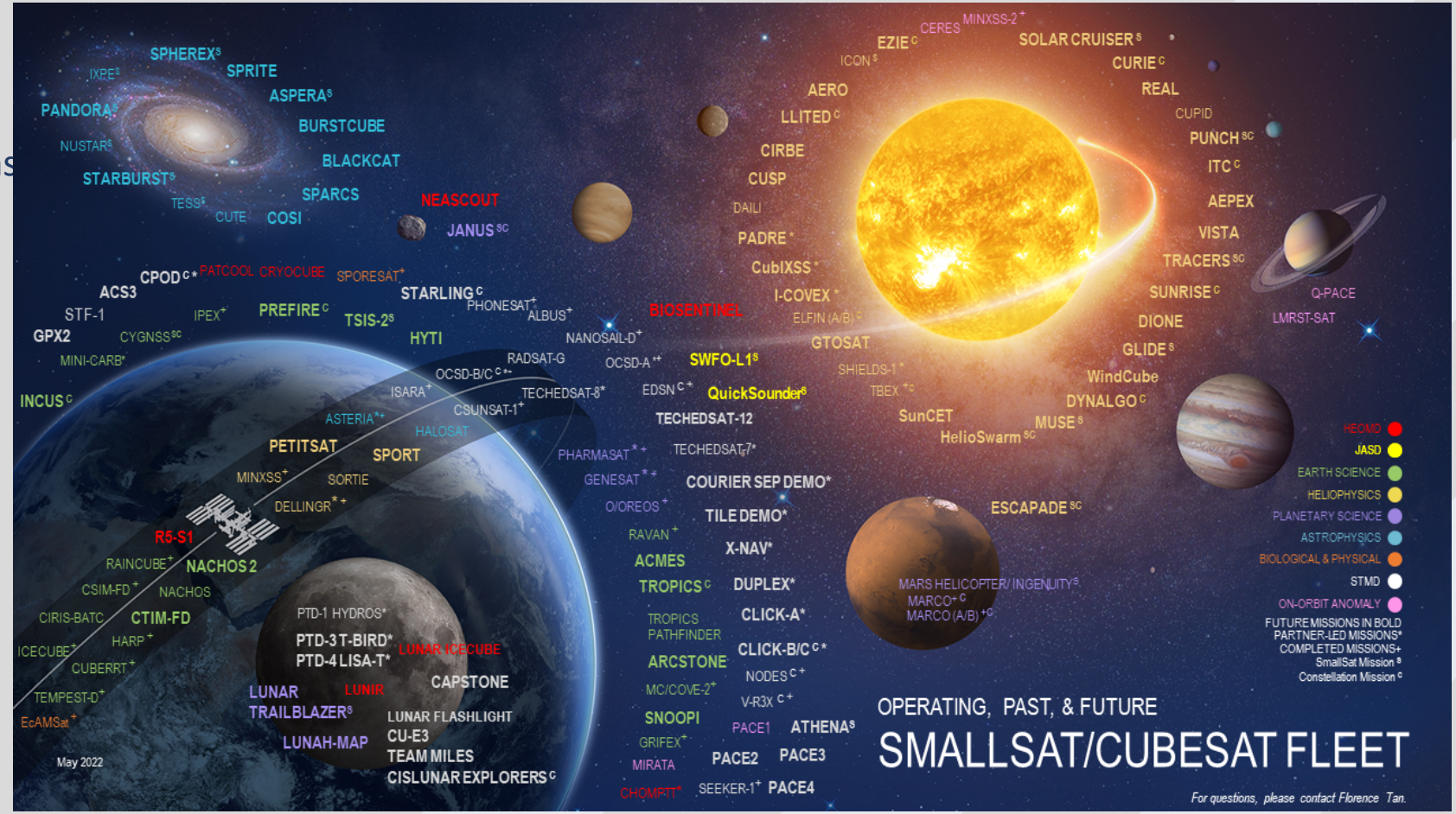


HIAD Graphics from: NASA.gov

Motivation

- **Exploring beyond Low Earth Orbit**
  - Interplanetary travel
  - Innovative and lower cost options are needed
- **SmallSat technology**
  - Smaller form factors
  - Lower cost for Big science
- **Ridesharing opportunities**
  - Secondary payload adapters

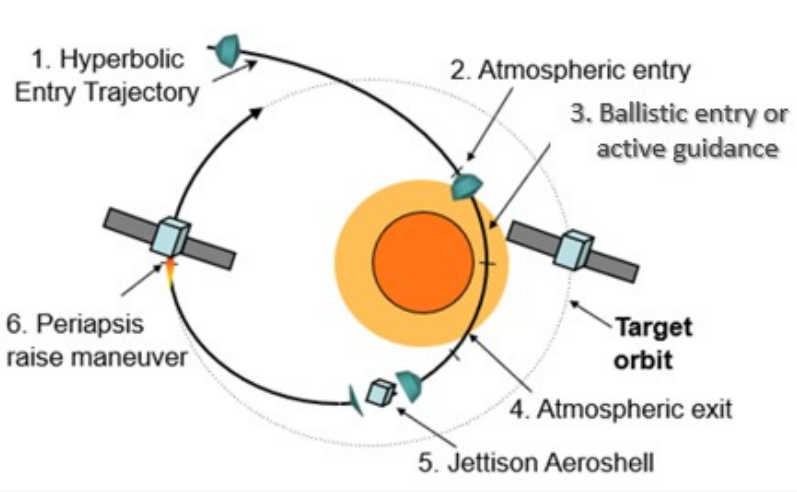
Image Credit: Electrodynamic Technologies



Graphic Credit: NASA's Goddard Space Flight Center

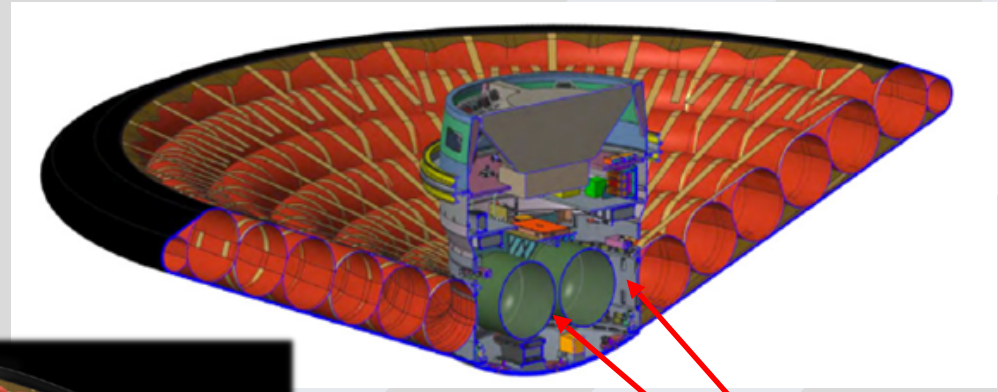
SmallSats for Interplanetary Missions Using HIAD Technology

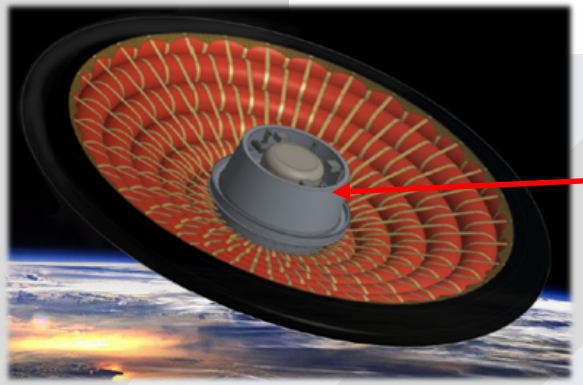
- **SmallSats** - ideal vehicle platform for lowering mission costs.
- **Interplanetary travel**
  - Higher velocities
  - Higher orbit insertion costs using traditional methods
- **Aerocapture**
  - Can reduce propulsive burn requirements
  - Aeroshell required



graphic adapted from (M. Munk & T. Spilker, 2008)

- **HIAD – Hypersonic Inflatable Aerodynamic Decelerator**
  - Inflatable aeroshell with a stacked toroidal design
  - Current work – LOFTID (Low-Earth Orbit Flight Test of an Inflatable Decelerator)
    - Uses a 6-meter diameter HIAD design





HIAD graphics: LOFTID fact sheet, NASA.gov

SmallSat HIAD Feasibility Study

Purpose:

To determine the feasibility of using SmallSat-sized HIAD aeroshell designs for planetary orbit insertion via aerocapture for **Mars, Venus, and Earth** missions.

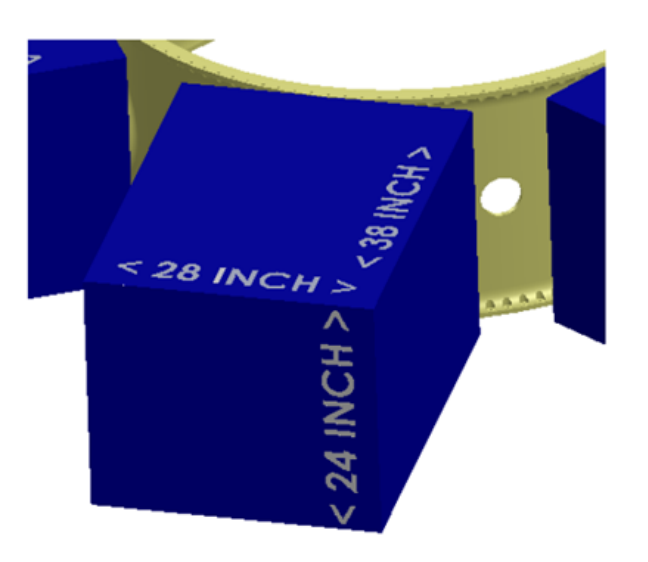
- **Candidate SmallSat HIAD sizes**
  - Secondary payload adapter specifications were used for size constraints.
  - Identified candidate sizes – 0.5m, 1m, 1.5m, 2m, and 2.5m diameter designs.
    - LOFTID's 6-meter HIAD design was used as a basis for scaling.
- **Trajectory performance analysis**
  - Limiting case 1 – Maximum Vehicle Mass
  - Sensitivity studies – dispersion analysis of Aerodynamic, Atmospheric, and Entry Condition parameters
  - Limiting case 2 – Thermal Protection Limits

Case 1 – Maximum Vehicle Mass

Typical secondary payload adapter constraints:

- Mass – 450 kg per port
- Volume – 24 by 28 by 38 inches

(Std. ESPA Heavy configuration w/ 5/16” fasteners)



Volume constraint for Std. ESPA

Trajectory Performance Analysis:

- Nominal cases and behavior established using a hyperbolic entry aerocapture scenario with ballistic entry and no active guidance.
- Design sensitivity study identified significant entry condition sensitivities, indicating active guidance will be needed to insure desired insertion conditions

What was learned from Case 1:

- **All** candidate SmallSat-sized HIADs could be used for orbit insertion via Aerocapture at Mars, Venus, and Earth.
- For mission planning - active guidance will be needed.

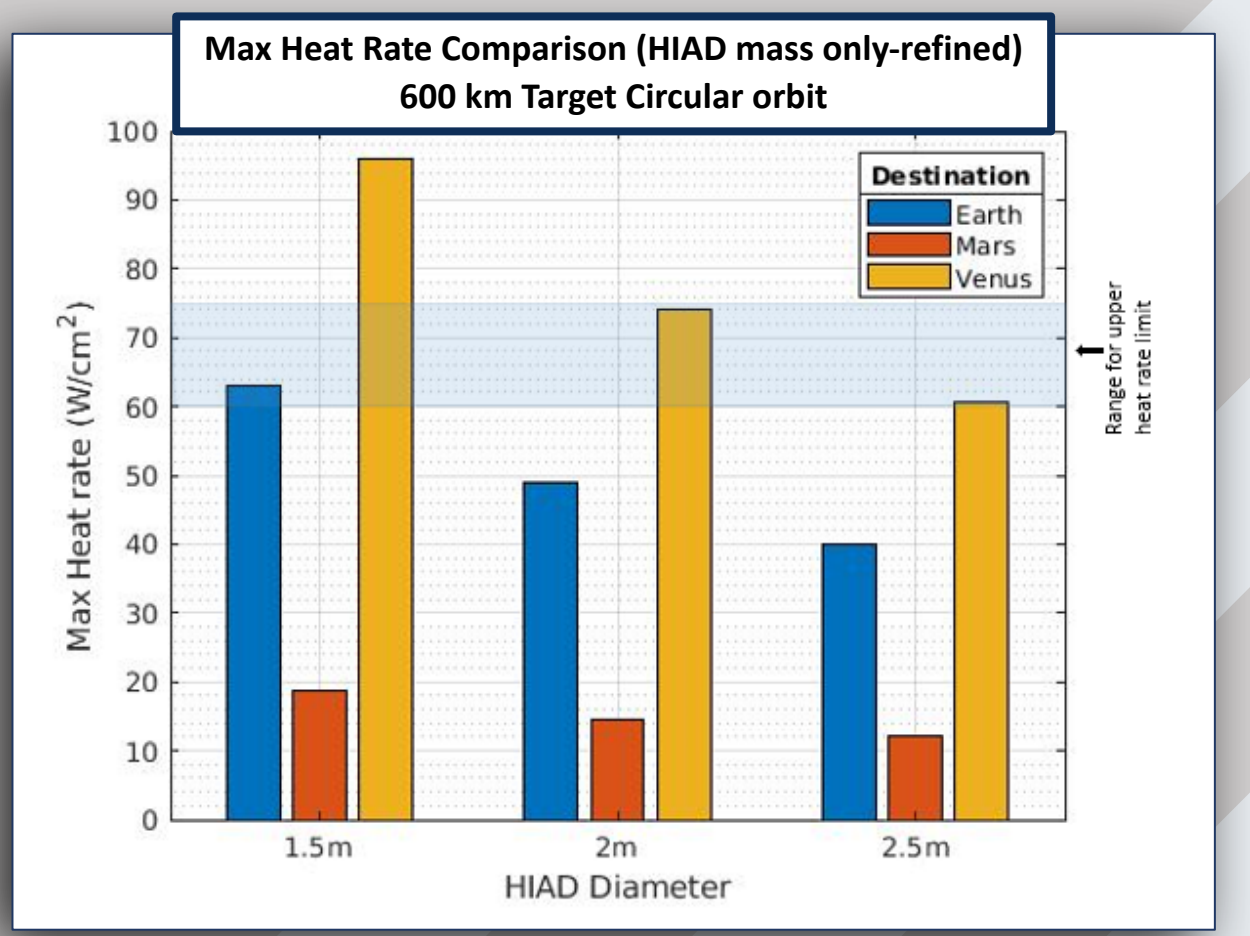
Case 2 – Thermal Protection Limits

For SmallSat-sized HIADs to be feasible:

- Heating rate target - **75 W/cm²** or less based on current Flexible Thermal Protection System limits (F-TPS)
  - All heating rate results from the first limiting case were above this limit

Heating rate reduction efforts:

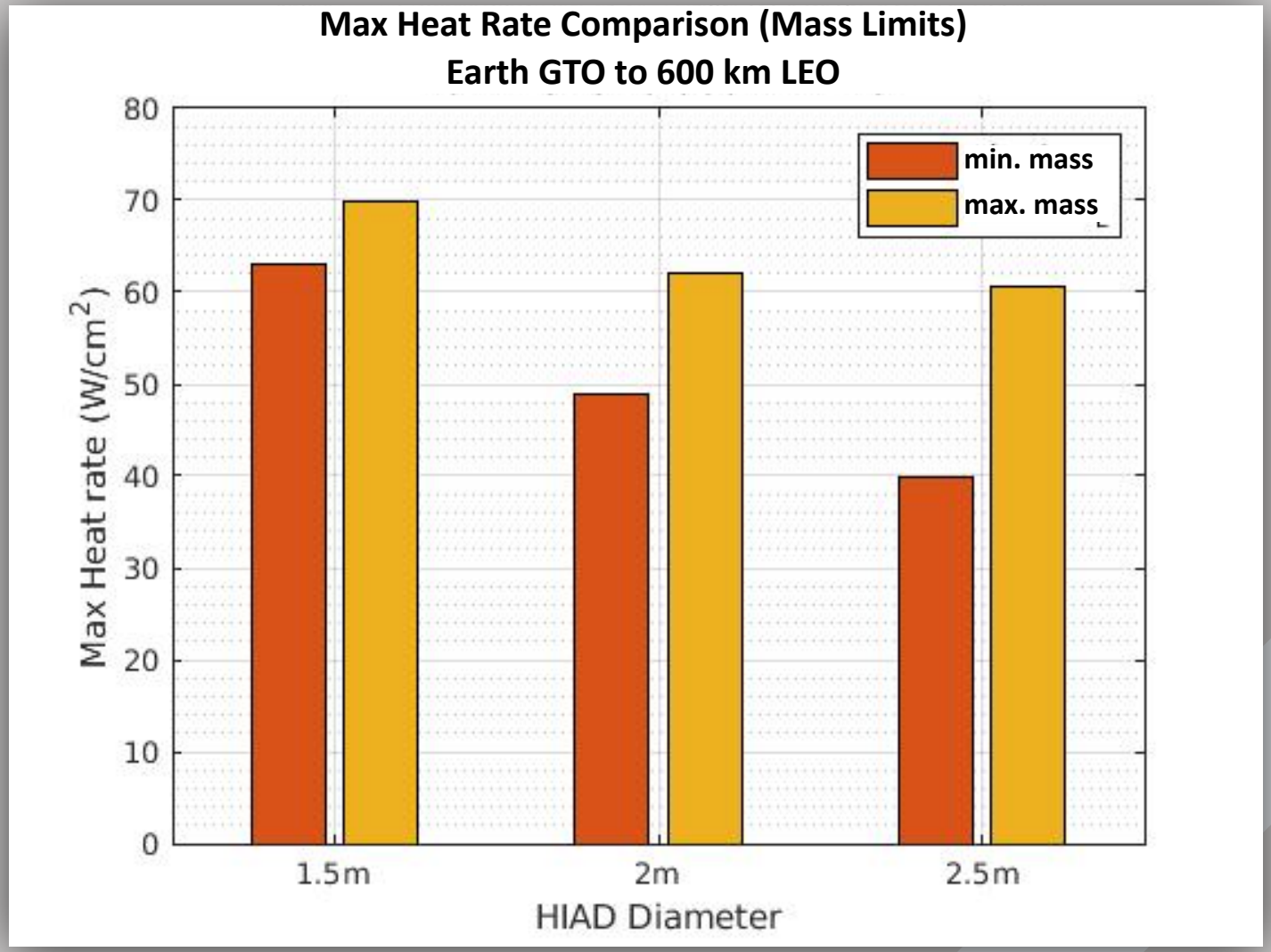
- Refined mass estimates
  - A materials-based approach - Forward Segment
  - MATLAB-based tool - Inflatable Structure
- Entry velocity variation
  - Venus - reduced to 10.3 km/s
  - Earth - reduced to 10.3 km/s to simulate an approach from a GTO - Geostationary Transfer Orbit



Summary of Refined Mass Estimates

HIAD design	Initial Estimate (kg)	Reduced Estimate (kg)
1m HIAD	105	38
1.5m HIAD	156	60.8
2m HIAD	202	85.4
2.5m HIAD	257	111.2

Exploring Potential Payload Capacity (Earth)



1.5m diameter:
Min. mass = 60.8 kg
Max. mass = 75 kg

2m diameter:
Min. mass = 85.4 kg
Max. mass = 140 kg

2.5m diameter:
Min. mass = 111.2 kg
Max. mass = 260 kg

Potential Payload Capacity:
For Earth-
1.5-meter HIAD: up to **14 kg**
2-meter HIAD: up to **55 kg**
2.5-meter HIAD: up to**149 kg**

Venus – 2.5-meter: ~40kg

*max. mass includes HIAD mass plus a payload & min. mass is HIAD mass only

Conclusions & Discussion

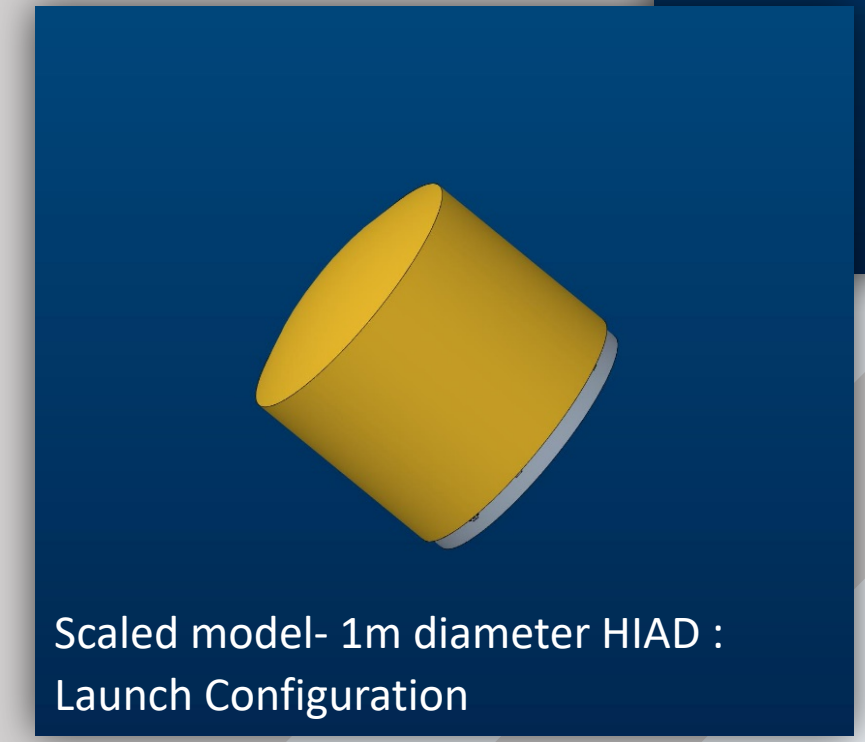
- With these promising results, this study suggests that SmallSat-sized HIADs are feasible for interplanetary science missions and are worthy of further exploration.

- Suggested Future Work:
  - Consider additional destinations
  - A higher-level concept review
    - Engineering review of the Inflatable Structure and Forward Segment
    - Identify system components; GNC, propulsion, inflation system, etc.
    - Consider lifting configurations/designs.

Thank You!

Questions?

Scaled model -1m diameter HIAD: Entry Configuration



Scaled model- 1m diameter HIAD : Launch Configuration