The Hypersonic Inflatable Aerodynamic Decelerator (HIAD) Mission Applications Study

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The HIAD Project

- The general approach is to simulate a trade space customized to each mission architecture. Typical trade parameters include:
  - Entry flight path angle
  - Entry velocity
  - Entry mass
  - HIAD diameter
  - Iterate on HIAD mass in consideration of the trajectory head load and dynamic pressure
  - Use the Entry Descent and Landing Systems Analysis, Exploration Feed Forward mass model3.
  - Apply system constraints (e.g., heat rate limits) to identify regions of feasibility
  - Select design points based on mission objectives (e.g., landing altitude)
  - Perform conceptual level design of the entry system to better understand the impact of HIAD technology infusion into the concept of operations
  - Also validate and informs updates to trade-level mass models
  - Revisit trade space and recommended HIAD sizing as required
  - Deviations from this approach as well as additional assumptions are noted within the analysis plan of each mission investigated
- Example missions under investigation include:
  - Mars Direct Entry: Mars Southern Highlands
  - Launch Vehicle Asset Recovery: SpaceX Falcon 9

Launch Vehicle Asset Recovery

- Recovery of launch vehicle assets has the potential to reduce the overall cost of launch services while avoiding further proliferation of orbital space debris
- The Launch Asset Recovery Study investigates the potential benefits of a HIAD in recovering launch vehicle assets (e.g., first/second stage boosters and avionics)
- Use HIAD to enable recovery by delivering to MCCV chute deployment condition

Booster Recovery Space Traders Parameters

- First Stage:
  - Mass of First Stage is varied from 15 to 22 Metric Tonne: First Stage is 19.241 dry
  - Initial Relative Velocity varies from 2,700 to 5,200 m/s
  - HIAD diameter varies from 3.5 to 15 m

- Second Stage:
  - Mass of Second Stage is varied from 3 to 4 Metric Tonne: Second Stage is 3.1 dry
  - Descend delta-v varies from 100 to 300 m/s
  - HIAD diameter varies from 3.5 to 15 m

Results:

- For the First Stage, the optimal solution is a 10-m HIAD with an estimated weight of 1.5 MT (HIAD enables first stage recovery)
- For the Second Stage, the optimal solution is 6-m HIAD, with an estimated weight of 0.25 MT (HIAD provides margin to second stage recovery)

Mars Southern Highlands

- Discovery of flowing water in craters throughout the southern highlands raises interest in this potential landing region
- Potential candidate landing sites:
  - Terra Sirenum (Mallis) - 40 lat, 210 lon, 1.5 km AR
  - Sirenus Fossae (Mars Express) - 34 lat, 200 Lon, 3 km Alt

The Mars Southern Highlands study is investigating several architectures

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Architecture 01.01.06 setup:
- HIAD straight to subsonic retropropulsion
  - MSL-class mission (3400 kg entry mass) with MSL-like component masses
  - Aerodynamic database based on High Energy Atmosphere Reentry Test vehicle development (approximately a 55 deg. spherecone)
  - Aerobraking based on Sutton-Graves and Tauber-Sutton convective and radiative heating indicators (with margins applied)

Results:

- Staging condition drives HIAD sizing
- 15-meter HIAD subsonic retropropulsion allows MSL-class payload to ~4 km MOLA with no supersonic or parachute events
- Staging at higher Mach numbers could allow significantly more payload mass
- Landed payload mass nearly constant over landing sites investigated (~0.4 km MOLA) elevation

CONCLUSIONS & OUTLOOK

- Hypersonic Inflatable Aerodynamic Decelerators have the potential to significantly enhance space and planetary exploration missions
- The HIAD Mission Applications Study is in the process of identifying and quantifying specific benefits through a full systems engineering view of HIADs within the context of high priority missions
- In the coming year, modeling and analysis performed within the HIAD Mission Applications Study will improve the fidelity of current investigations and explore additional missions, which target destinations such as Venus, Titan, and Mars

References: