Planned Flight of the Terrestrial HIAD Orbital Reentry (THOR)

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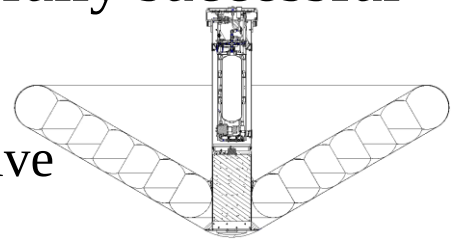
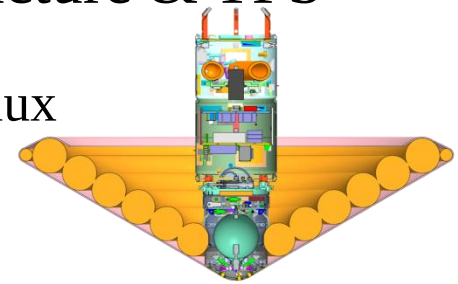
Background (1 of 2)

- NASA Langley Research Center has been developing Inflatable Aeroshell technology for over 10 years.
  - Inflatable Reentry Vehicle Experiment (IRVE) launched 2007; sounding rocket nose cone did not release reentry vehicle
  - IRVE-II launched 2009: "build-to-print" reflight, fully successful

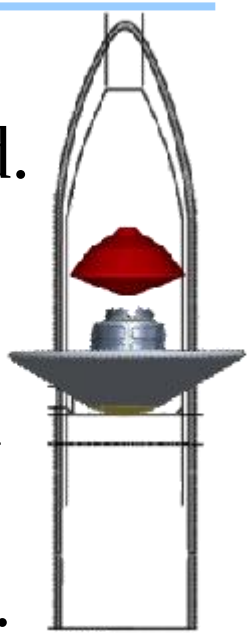


    - Inflated in space to 3m diameter, 3.5psi, 125kg RV
    - Reentry from 218km apogee: 8.5G's, 2W/cm^2 peak flux
    - Confirmed trajectory and heating models were conservative
    - Demonstrated inflation, maintained pressure differential
    - Demonstrated stable flight in hyper/super/trans/subsonic regimes
  - IRVE-3, launched 2012: Improved Inflatable Structure & TPS

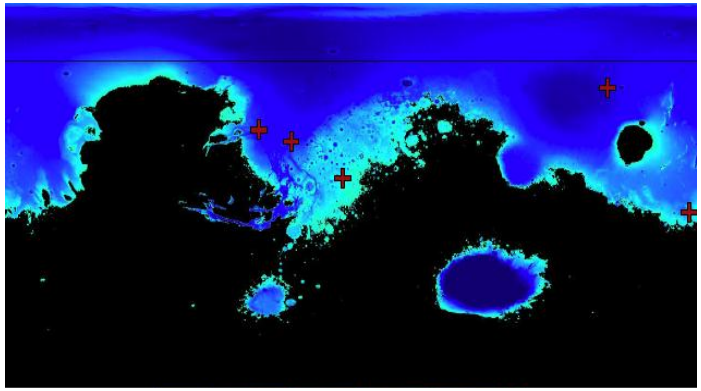


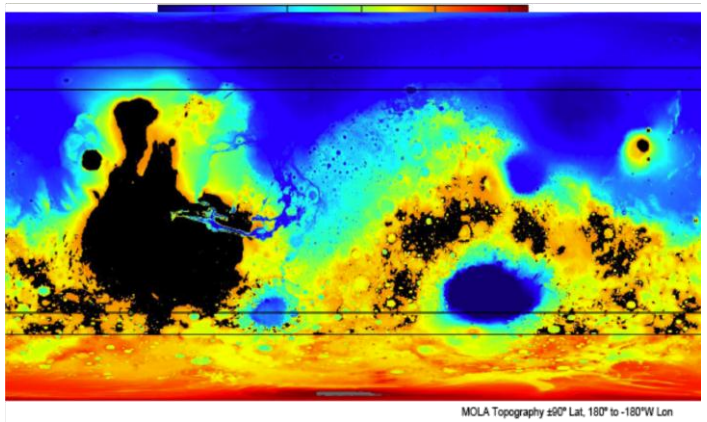
    - Inflated in space to 3m diameter, 20psi, 280kg RV
    - Reentry from 469km apogee: 20.2 G's, 15 W/cm^2 peak flux
    - Demonstrated survival of reentry heating environment
    - Demonstrated L/D by CG offset of Inflatable Structure
  - HIAD project continued developing improved structure and TPS in parallel with IRVE flight tests

Background (2 of 2)



- Entry mass at Mars is limited by the size of the reentry capsule that will fit in launch vehicle shroud.
- Inflatable approach allows a larger aeroshell to be stowed inside the launch vehicle shroud.
- Landing site selection at Mars is limited by ballistic coefficient (Mass/C_DArea) of reentry capsule.
- Inflatable aeroshell can reach more of Mars surface.

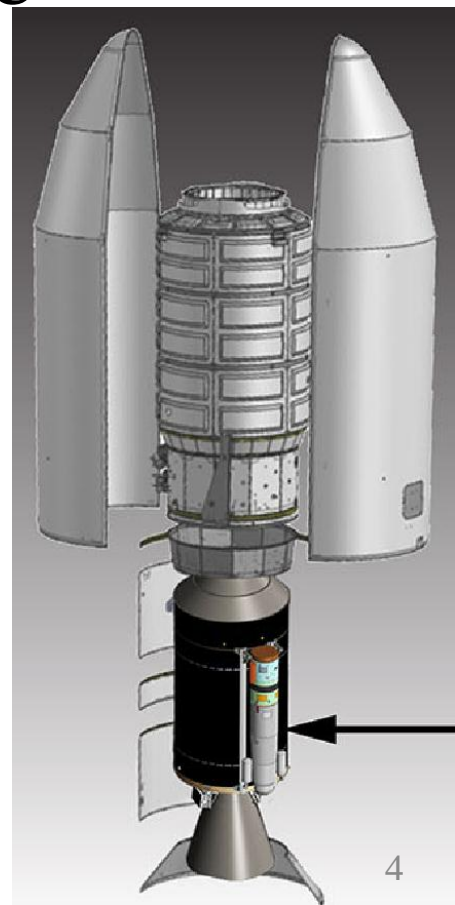




- Increased capability is needed for higher mass, higher altitude, & eventual human missions.

THOR Mission Concept

- Inflatable aeroshell reentry flight demo from LEO
- Higher energy than previous suborbital tests
  - 7.8km/s at atmospheric interface, up from 2.6km/s
- Using existing IRVE-3 "Built to Print" centerbody and 3.7m diam inflatable aeroshell with "second generation" inflatable structure and TPS materials
- Secondary payload on Antares flight to ISS
  - Fits between 2.3m diam Antares second stage (CASTOR 30XL) & 3.9m diam payload fairing
- After Cygnus cargo vehicle separates to go to ISS, THOR separates for reentry demo
- THOR reentry heat pulse ~4min long, max flux 40-50W/cm^2; max deceleration 8-10G's
- Second generation TPS has passed longer ground tests with peak heat flux of 65W/cm^2



Mission Comparison

- LEO reentry test of inflatable aeroshell is good analog to large payload (>1,000kg) delivery flight to Mars surface

Parameter	IRVE-II	IRVE-3	THOR	ISS Down-mass / Mars Precursor
HIAD Diameter (m)	3	3	3.7	8-12
Entry Mass (kg)	125	280	315	4500-6500
Peak Heat Rate (W/cm^2)	2	15	40-50	30-40
Total Heat Load (kJ/cm^2)	0.02	0.2	9-12	5-7

Aeroshell Upgrades

- Structure retains stacked-toroid design to allow inflation to flight configuration before reentry
- Second generation inflatable structure replaces Kevlar fiber (okay briefly at 250C) with Zylon (usable at 400C)
- Second generation flexible TPS replaces high-temp Nextel fabric over Pyrogel insulation with higher-temp Carbon-SiC fabric over carbon felt insulation
- All the second generation materials still compatible with traditional HIAD approach of hard-packing into a small volume for launch and deploying in flight
- Fabricated 6m diameter HIAD inflatable structure, tested in NFAC 40x80' tunnel at NASA Ames

Other Changes

- Adding two solid rockets for de-orbit capability
  - Current options: STAR 6B's at WFF, or Navy JATO's
- Increasing ACS performance (Argon → Freon)
  - WFF NIACS system has numerous flights with each
  - System needs to point THOR for de-orbit burn as well as for reentry
- Reconfiguring inflation and pressure sense lines for inflatable structure's additional toroid
  - Analysis: inflation to 15psi sufficient for reentry loads
- Adding hardened data recorder
  - Reentry is out of range of ground stations, & footprint is too large to be covered by a few boats
  - Some position & attitude data in real time via satellite
  - Recorder released for splashdown, reports location via satellite

Flight Instrumentation

- Several dozen thermocouples (TC's) will measure TPS temps in flight; heat flux & pressure gauges on nose
- Additional TC's on centerbody & aft surface of inflatable
- GPS position, inertial measurement unit, accelerometers
- Engineering systems data such as inflation pressures, position of the CG offset system, power system voltages and currents, and ACS actions
- Video from 4 cameras near the aft edge of the centerbody provide 360deg coverage of the aeroshell.

Future Plans

- Authority to Proceed with THOR is anticipated by the start of fiscal 2015, with flight in 2016. (Antares launches to ISS about every 6 months.)
- Potential future uses of HIAD technology include delivery of more massive payloads to the surface of Mars at higher altitudes than possible with a rigid capsule, and Earth reentry protection for valuable hardware that currently burns up, such as launch vehicle engines or ISS hardware too large to fit in the existing Soyuz or Dragon captules.

THOR

Terrestrial HIAD Orbital Reentry

Hypersonic Inflatable Aerodynamic Decelerator (HIAD)

National Aeronautics and Space Administration

THOR Mission Highlights

- Orbital velocity reentry flight demonstration of advanced inflatable aeroshell
- Validates structural and thermal performance capability against mission relevant flight loads
- Launches from the Wallops Flight Facility as secondary payload on an Orbital Sciences Corporation Cargo Resupply Services flight to the International Space Station
- Trajectory data received in real time through Iridium network
- Performance data recorded on board, unit jettisoned before splashdown