National Aeronautics and Space Administration

Human Mars Lander Design for NASA's Evolvable Mars Campaign

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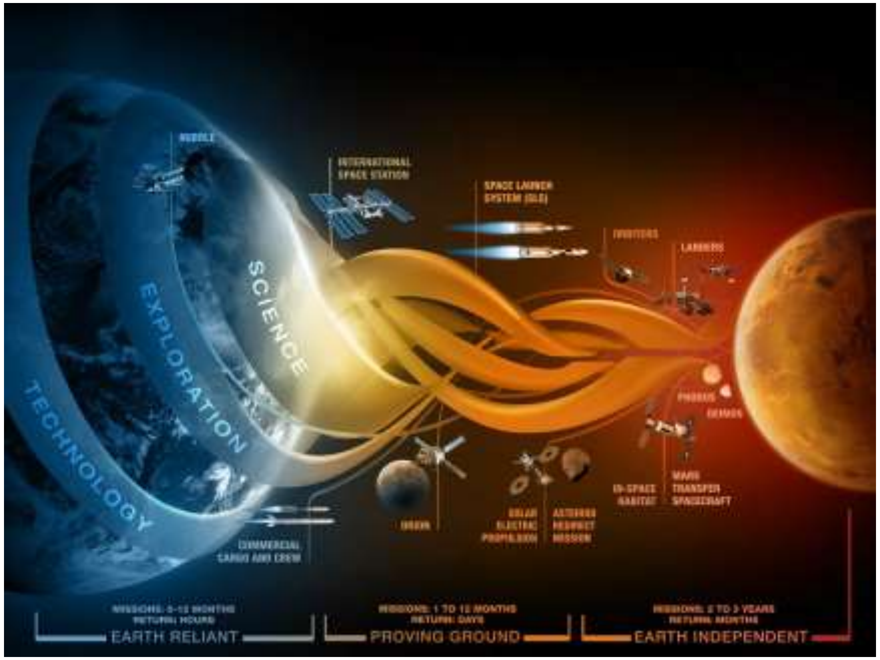
Evolvable Mars Campaign

- **NASA's Evolvable Mars Campaign is an ongoing series of architectural trade analyses to define the capabilities and elements needed for a sustainable human presence on the surface of Mars.**

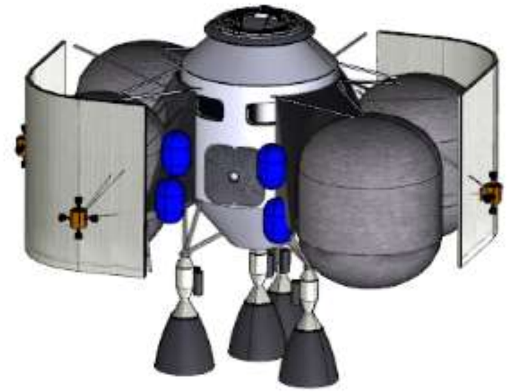
- **This activity informs near term investment priorities**



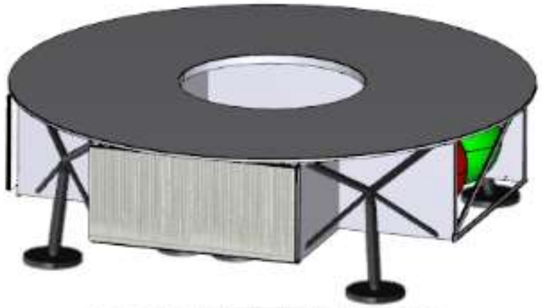
- **The human Mars lander design impacts transportation architecture and Mars surface systems**
  - Launch fairing options and in-space transportation system performance requirements
  - Protection of surface payloads during entry, and access to and offloading of payloads on the surface

Human Mars Entry Descent and Landing System

- **Cargo**
  - Ascent vehicle, habitats, etc.

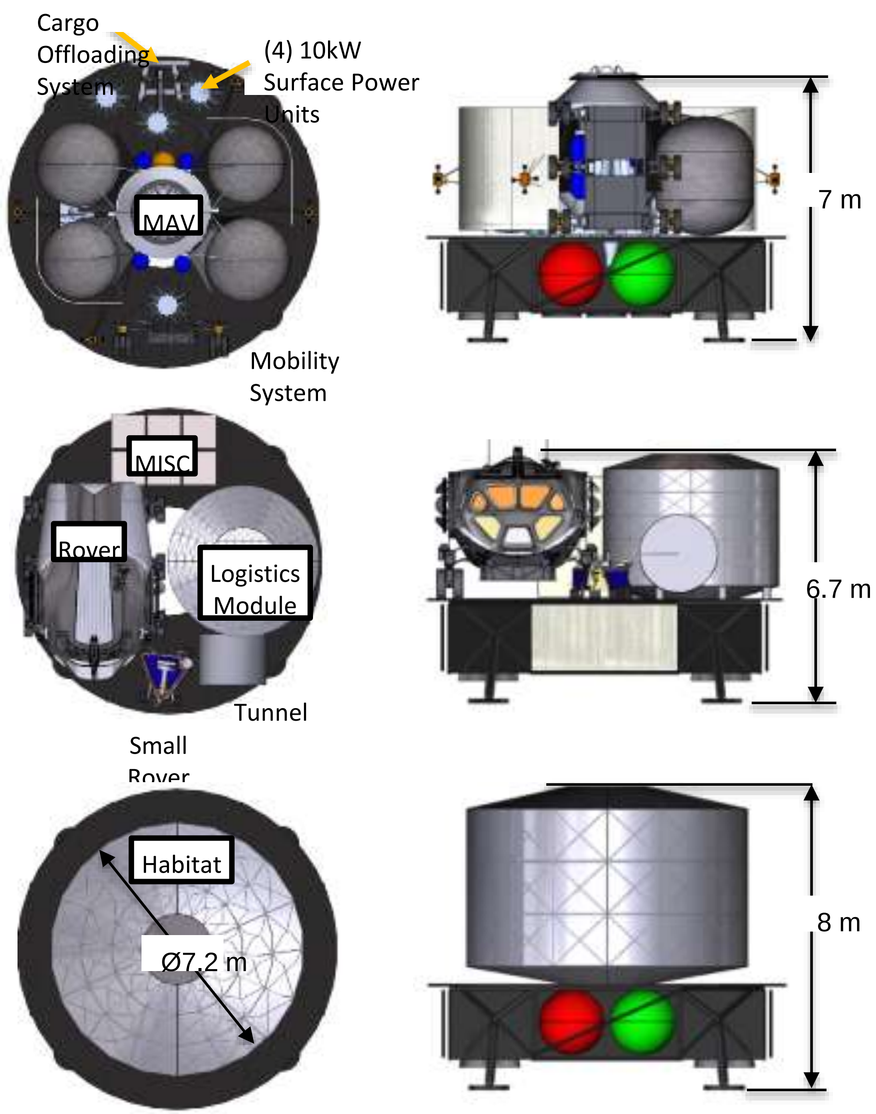


- **Mars Descent Module (MDM)**



- **Entry System**

Potential Cargo

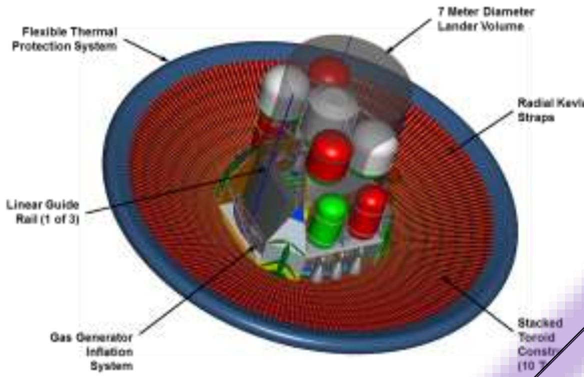


- **Many different cargo elements needed to support a surface mission**
  - Mars Ascent Vehicle (MAV)
  - Pressurized Rover
  - Logistics Modules
  - Habitats
  - Surface Power Systems
- **Cargo landings precede crew landing and demonstrate the same entry, descent and landing approach.**
- **Assumed 27mt of cargo delivered to the surface for this design. Future designs will focus on 20mt cargo capability**

Entry Technologies Considered for Human Missions

Inflatable

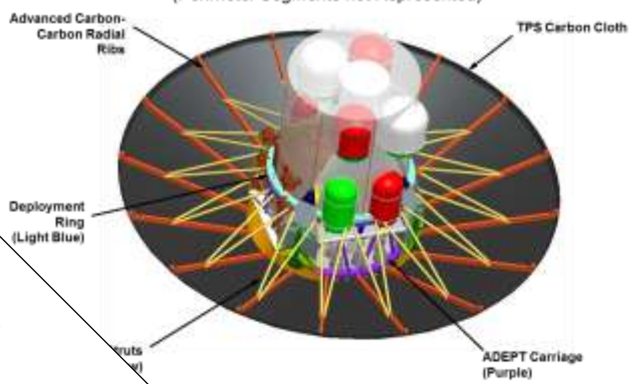
HIAD – Hypersonic Inflatable Aerodynamic Decelerator



Deployable

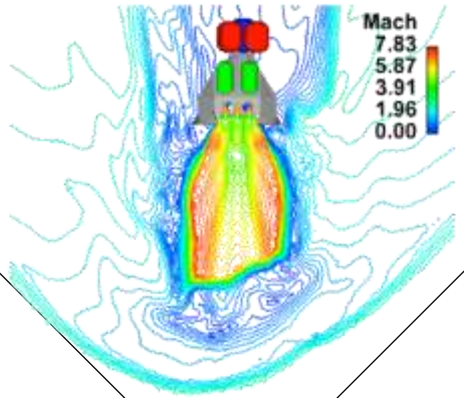
ADEPT – Adaptable Deployable Entry and Placement Technology

16 Rib Point Design Configuration
(Perimeter Segments not Represented)



Supersonic Retro-Propulsion

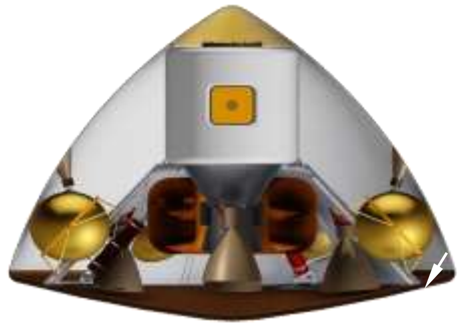
Common to All



Mid L/D

Rigid Structure

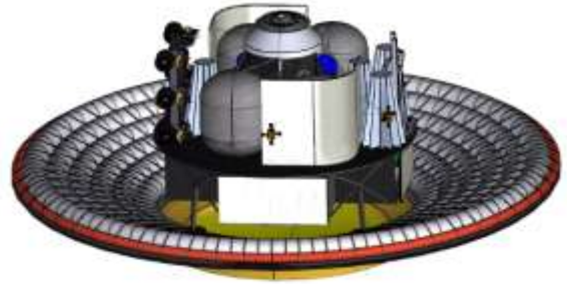
Capsule Concept



All configurations are for reference

HIAD Overview

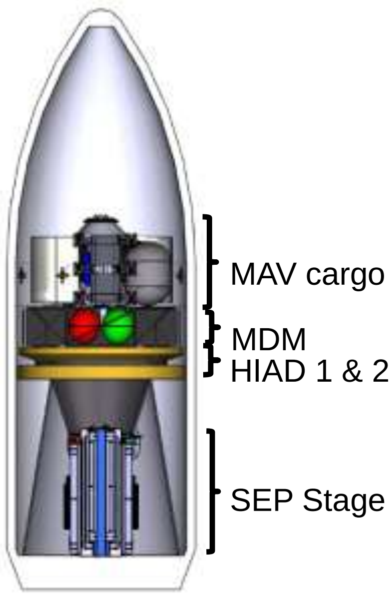
- **Inflatable technologies enable larger aeroshell to be stowed inside launch shroud.**
  - Inflation occurs prior to atmospheric entry.
  - Flexible TPS protects inflatable structure and payload from entry environments.
  - TPS is constructed of ceramic outer fabric with customizable layers of flexible insulation (such as carbon felt or Aerogel felt)
  - Inflatable structure utilizes braided fiber and fluoropolymer liner toroids stacked with pairing and radial straps



IRVE-3
Flight 2012

Mission Overview

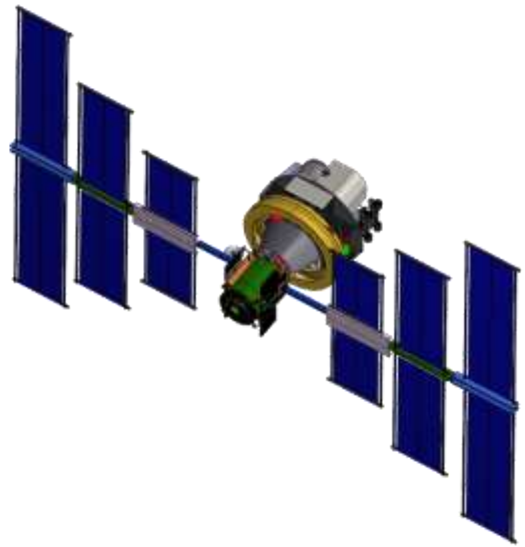
Launch



SLS Block 2 Launch Vehicle with 10-m Fairing

Launched with Solar Electric Propulsion transportation stage to elliptical Earth orbit

Earth to Mars Transit

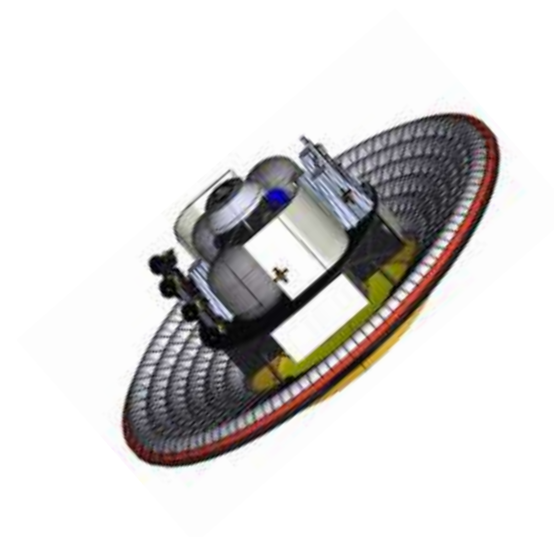


Spiral escape trajectory from Earth, 2.5 years (300kW)

Relies on SEP stage for power and comm

Several transportation options are currently under study in the EMC

Mars Arrival



Earth to Mars transit, 1.2 years (300kW)

Separation from SEP stage 2 days before Aerocapture

1st HIAD dedicated to Aerocapture

Mission Overview

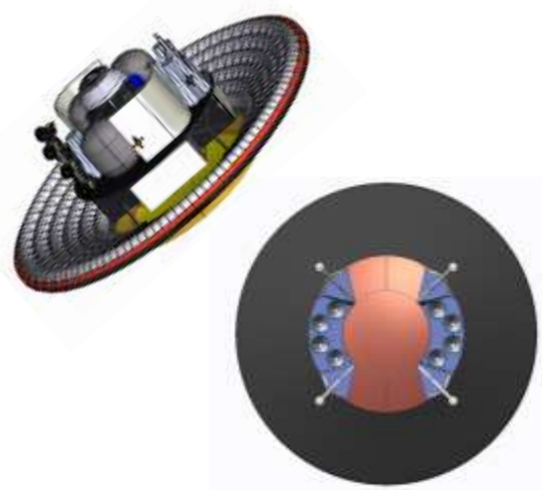
Mars Orbit Loiter

Landers transporting crew to the surface may loiter up to 1 year before docking with crew vehicle

Solar Arrays required

Aerocapture HIAD must be jettisoned before descent

Entry, Descent & Landing



2nd HIAD used for entry descent & Landing

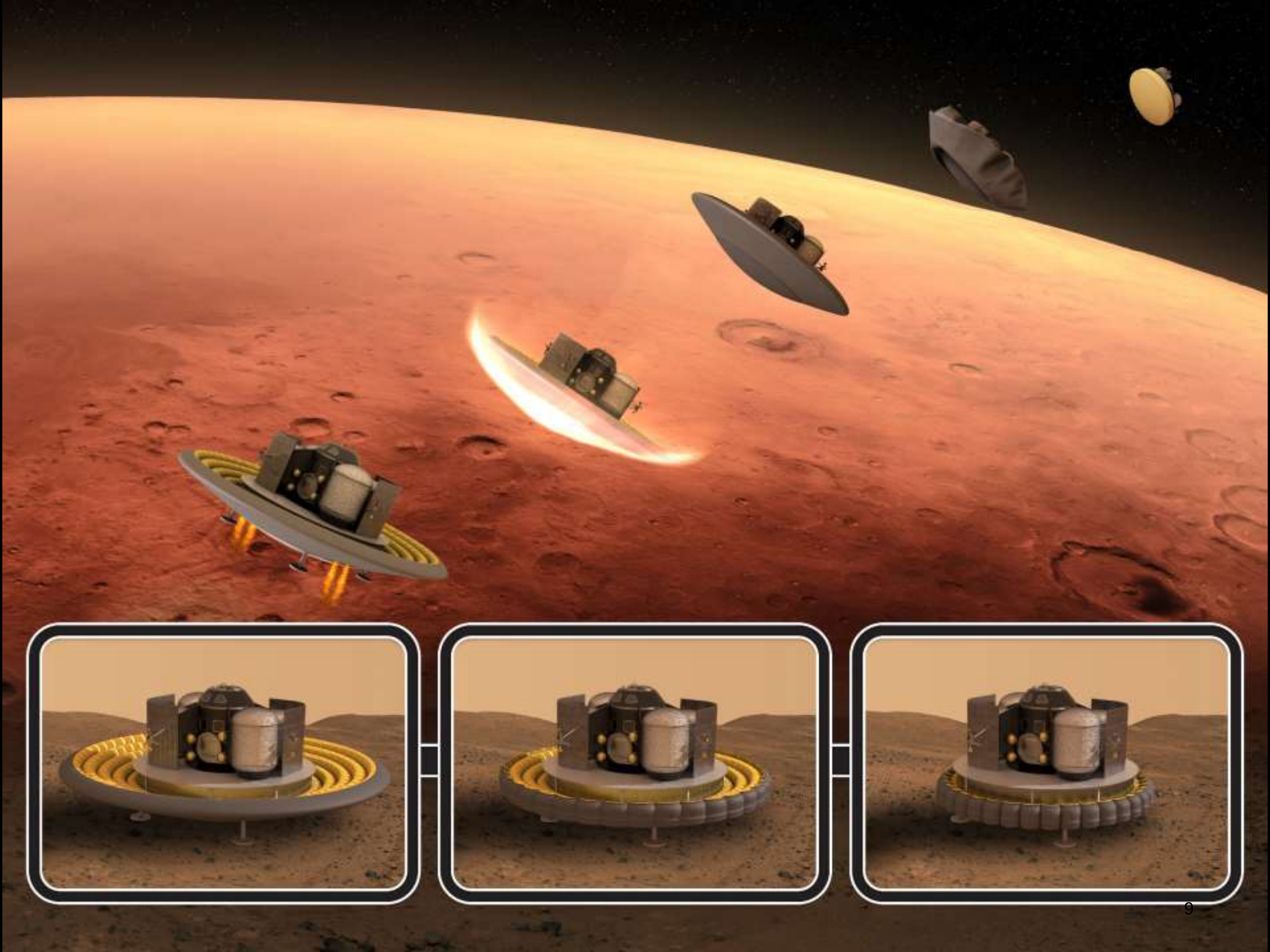
Entry system retained to the surface, doors in rigid heatshield open for engines and landing gear

Surface

HIAD retraction for cargo access.

Surface power connection < 24 hrs after touchdown

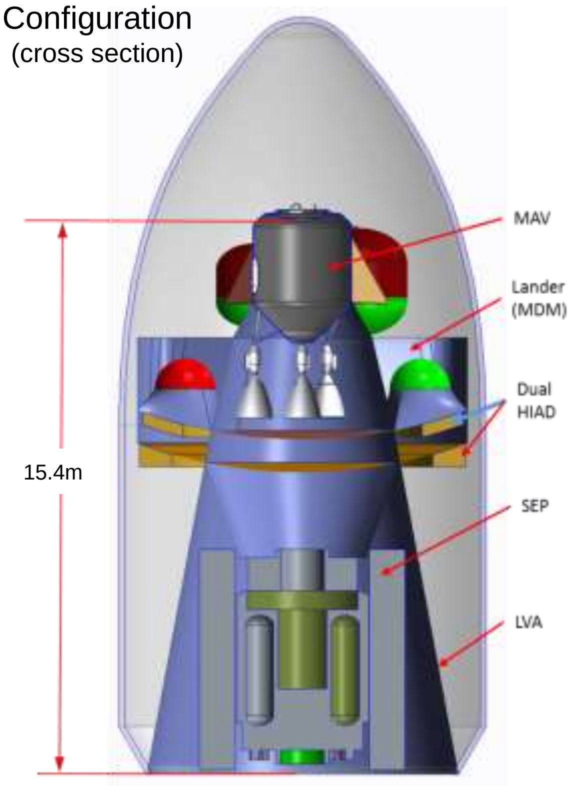
MAV & ISRU cargo require significant deployed radiator area not shown



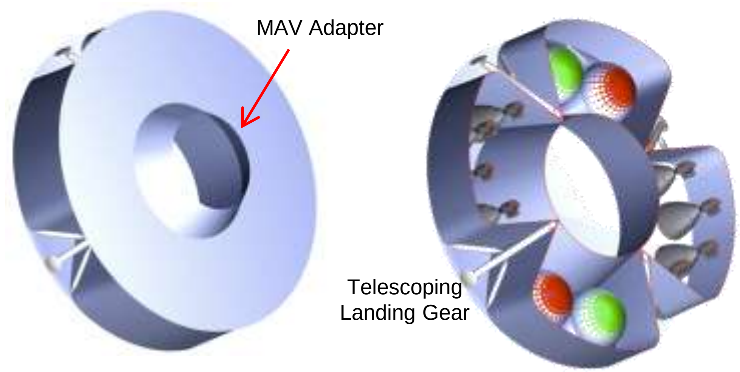
Vehicle Design

- **Structural design**
  - Design and mass driven by launch packaging and loads
  - Common descent module design for all cargo manifests
  - Cargo attachment and integration structure not included in lander mass

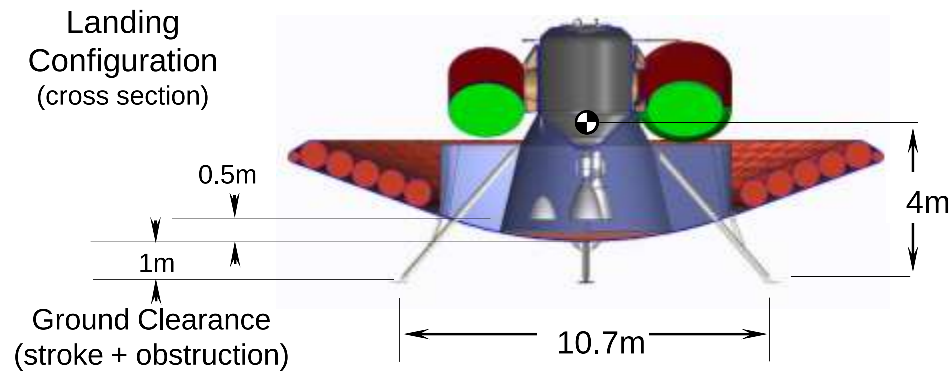
Launch Configuration
(cross section)



MDM Structure

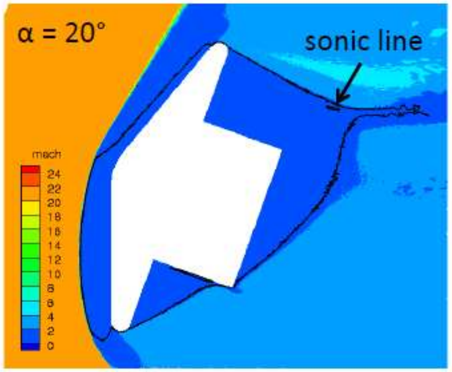


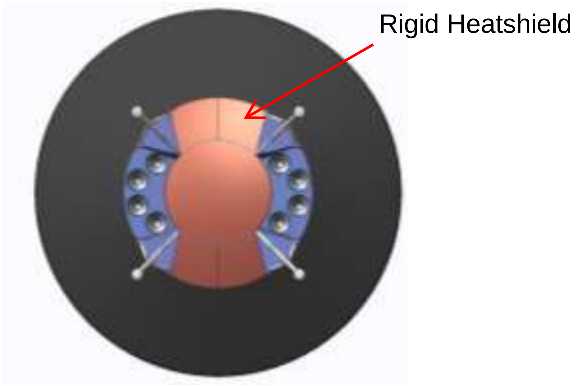
Landing Configuration
(cross section)



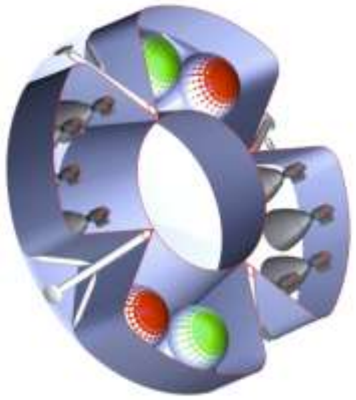
Vehicle Design

- **Aerodynamic decelerators**
  - Aerocapture HIAD 18.8 meters deployed
  - Entry HIAD 16.7 meters deployed
  - Initial flow impingement studies indicate some impingement and heating of cargo may be possible. Mitigation via cargo insulation or larger diameter decelerator is a topic for future study.



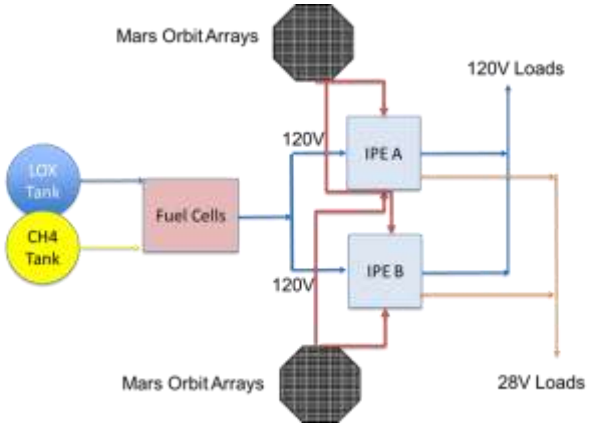


- **Propulsion**
  - Common engine design with MAV and in-space transportation options
  - oxygen and methane propellant
  - 8 main engines, 100 kN (22.5 klbf) thrust, 360 seconds Isp, pump-fed, 5:1 throttle
  - 445 N (100lbf) and 4455 N (1000lbf) RCS thrusters, pressure fed
    - Propellants drawn from main tanks and pumped to pressure in accumulators

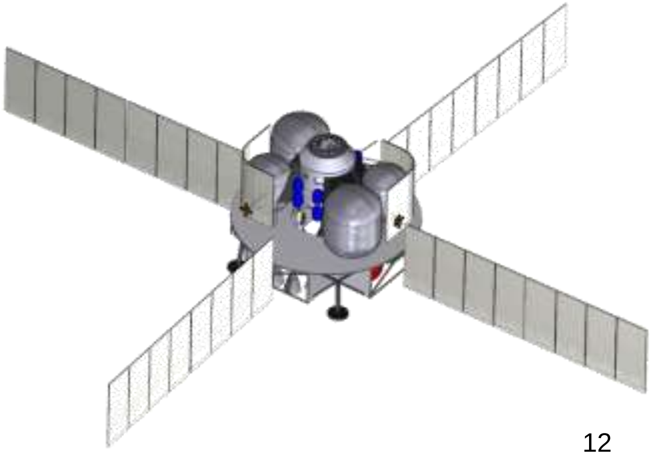


Vehicle Design

- **Power System**
  - Solar Array, 2 wings, 6.7 kW total at Mars for Mars orbit loiter
  - Solid oxide fuel cells using oxygen and methane reactants from propellant tanks, 3+1 5kW units for MDM & MAV support
    - 12 kW peak power during powered descent



- **Thermal**
  - Pumped fluid loop and radiators, water sublimator for peak loads
  - 4 90 deg K, 100 W cryocoolers on MDM
    - 1 needed for MDM, 3 for MAV support
  - Cargo Support: MAV and ISRU
    - Some MAV thermal support located on MDM to minimize MAV liftoff mass
    - ISRU propellant production may require 330 m^2 active radiator area, additional study required



Vehicle Design

- **Command & Data Handling**
  - 3 + 1 Flight computers, could be used as spares for other surface elements once landing is complete
- **Communications and Tracking**
  - Relay through Earth to Mars transportation stage during transit
  - Direct to Earth during Mars orbit loiter or relay through other Mars orbiters
    - 7 bps assumed through X-band, 35 kbps through Ka-band
- **Guidance Navigation & Control**
  - GN&C functions performed by transportation stage during transit to Mars
  - Safe precision landing within 100 meters of target requires terrain relative navigation and hazard detection and avoidance

Mass Breakdown

Mass Breakdown Structure		Predicted Mass (kg)
1.0	**Structures**	**4916**
1.1	MDM Primary Structure	1599
1.2	MDM Rings/Beams	355
1.3	MDM Structural Joints and Interfaces	494
1.4	HIAD Support Structure	847
1.5	Landing Gear	1620
2.0	**Propulsion**	**5570**
2.1	Main Propulsion System (MPS)	3933
2.2	Reaction Control System (RCS)	1636
3.0	**Power**	**1437**
3.1	Solar Power System	845
3.2	Fuel Cell Power System	210
3.3	Power Management and Distribution	382
4.0	**Avionics**	**413**
4.1	Command & Data Handling	214
4.2	Communications & Tracking	77
4.3	Guidance Navigation & Control	122
5.0	**Thermal**	**573**
5.1	Active cooling loops	200
5.2	Heaters	13
5.3	Radiators	360
6.0	**HIAD**	**10689**
6.1	Aerocapture HIAD	6081
6.2	EDL HIAD	4608
7.0	**Cargo**	**27000**
7.1	MAV + MAV-to-MDM Adapter	17334
7.2	ISRU	1512
7.3	ISRU Radiators & Deployment Mechanisms	1130
7.4	Other Cargo	7024
	Dry Mass	**50597**
8.0	**Non-Propellant Fluids**	**971**
8.1	Thermal Control	63
8.2	Fuel Cell Reactants	279
8.3	Propellant Residuals, Reserves, Fuel Bias, Boil off	629
8.4	Propellant Pressurization	16
	Inert Mass	**51568**
9.0	**Propellant**	**13774**
9.1	MPS Propellant	9067
9.2	RCS Propellant	4706
Total Mass		**65341**

The authors wish to acknowledge

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- The Evolvable Mars Campaign leadership for supporting this work.

- HIAD Project Team for providing expertise and guidance on HIAD performance and integration issues.

- And design team members: Dr. Dan Thomas, Mike Baysinger, Dave Paddock, John Teter, D.R. Komar, and Dr. Ashley Korzun for their valuable contributions to vehicle integration, configuration, structures and aerodynamics analysis.

Questions?