National Aeronautics and
Space Administration

Mission and Design Sensitivities for Human Mars Landers Using Hypersonic Inflatable Aerodynamic Decelerators

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Introduction

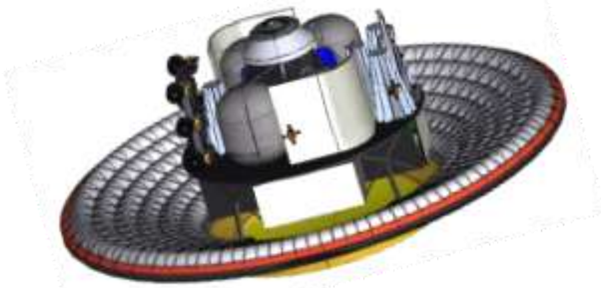
- **This paper explores the impact of human Mars mission architecture decisions on the design and performance of a lander using the HIAD entry system.**
  - Earth departure options
  - Mars arrival options
  - Entry Descent and Landing options

Related papers at this conference

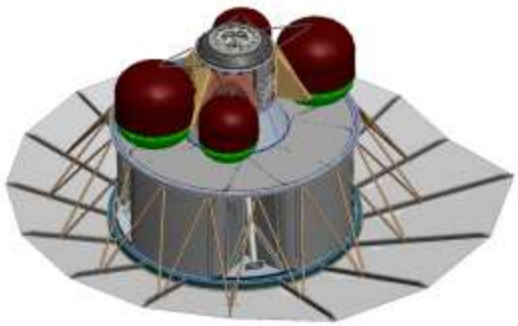
- "Human Mars EDL Pathfinder Study: Assessment of Technology Development Gaps and Mitigations" – Randy Lillard
- "Human Mars Mission Design Study Utilizing the Adaptive Deployable Entry and Placement Technology" – Alan Cassell
- "Impacts of Launch Vehicle Fairing Size on Human Exploration Architectures" – Sharon Jefferies

Entry Technologies

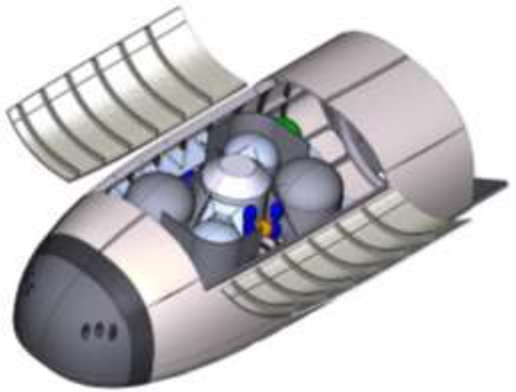
Inflatable
HIAD – Hypersonic Inflatable Aerodynamic Decelerator



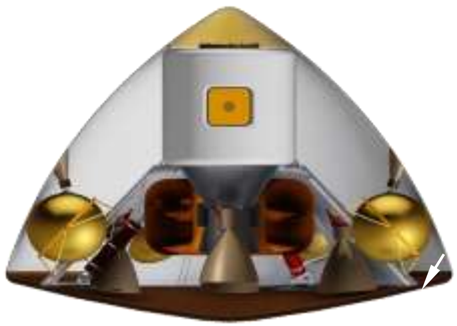
Deployable
ADEPT – Adaptable Deployable Entry and Placement Technology



Mid L/D
Rigid Structure



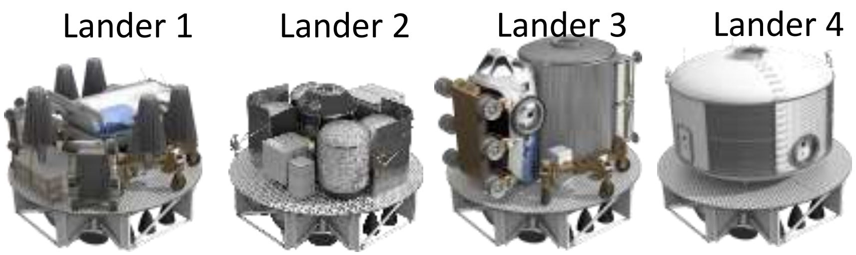
Capsule Concept

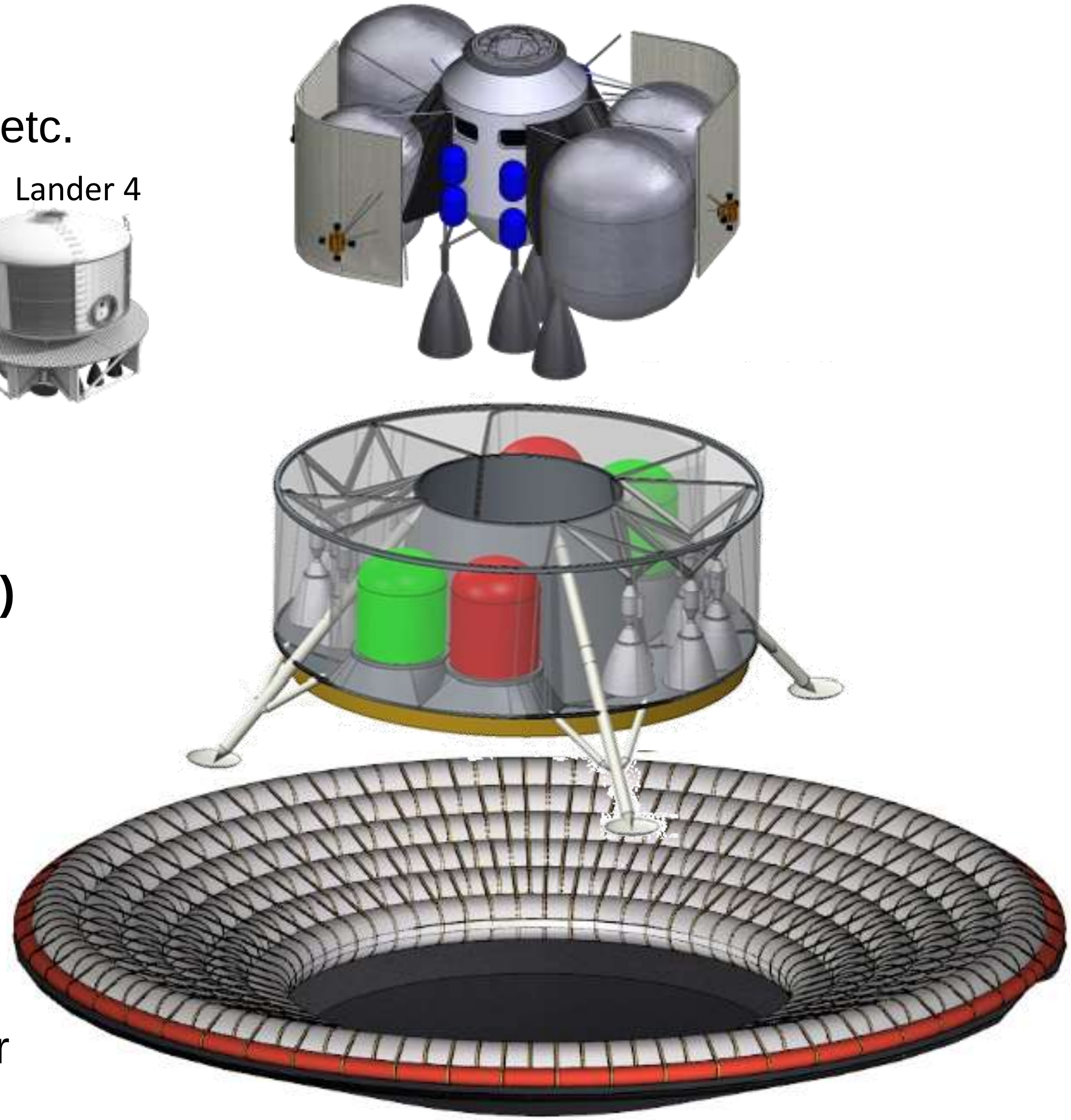


NASA is studying 4 entry system technologies for human missions. This paper is focused on the HIAD option.

HIAD Lander

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





- **Mars Descent Module (MDM)**

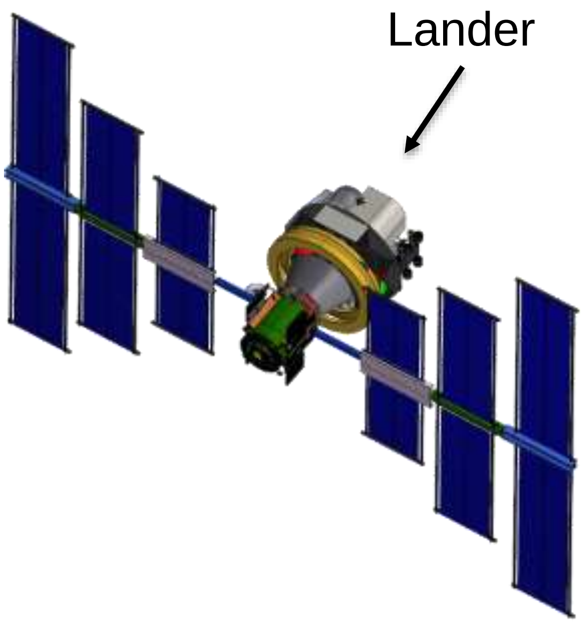
- **Entry System**
  - Hypersonic Inflatable Aerodynamic Decelerator (HIAD)


HIAD
Hypersonic Inflatable Aerodynamic Decelerators

Earth Departure Options

- **There are several in-space propulsion options for delivering cargo to Mars. Solar electric, chemical, and nuclear thermal have been studied.**

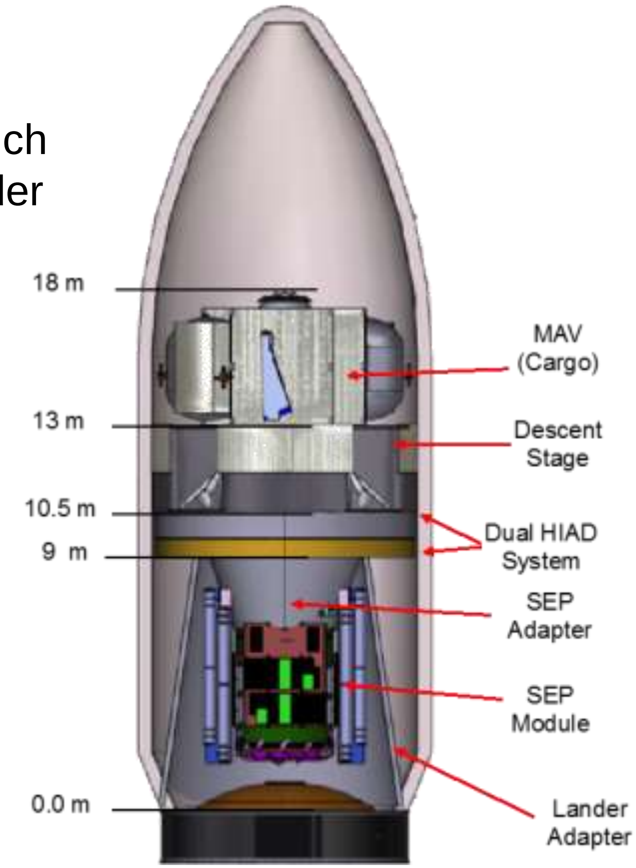
- **Solar Electric Propulsion offers 2 unique opportunities**
  - Single launch of lander and propulsion to Mars
    - Uses SEP one-way to Mars.
    - Spiral escape from high Earth orbit
  - Reusable Earth to Mars transportation
    - SEP + chemical hybrid vehicle
    - Cislunar aggregation

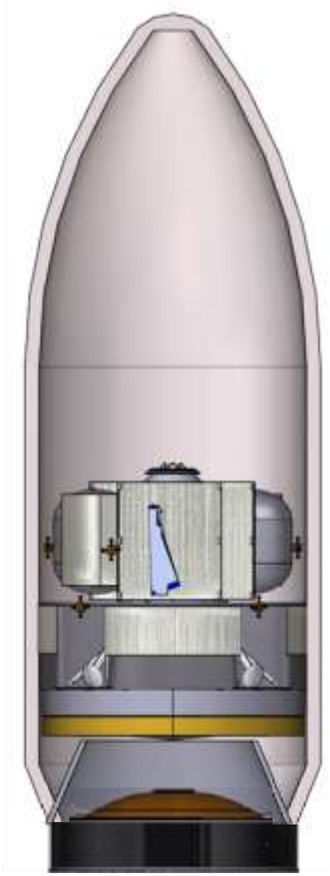


Earth Departure Options

Packaging in SLS 10m Fairing

Single Launch
SEP + Lander



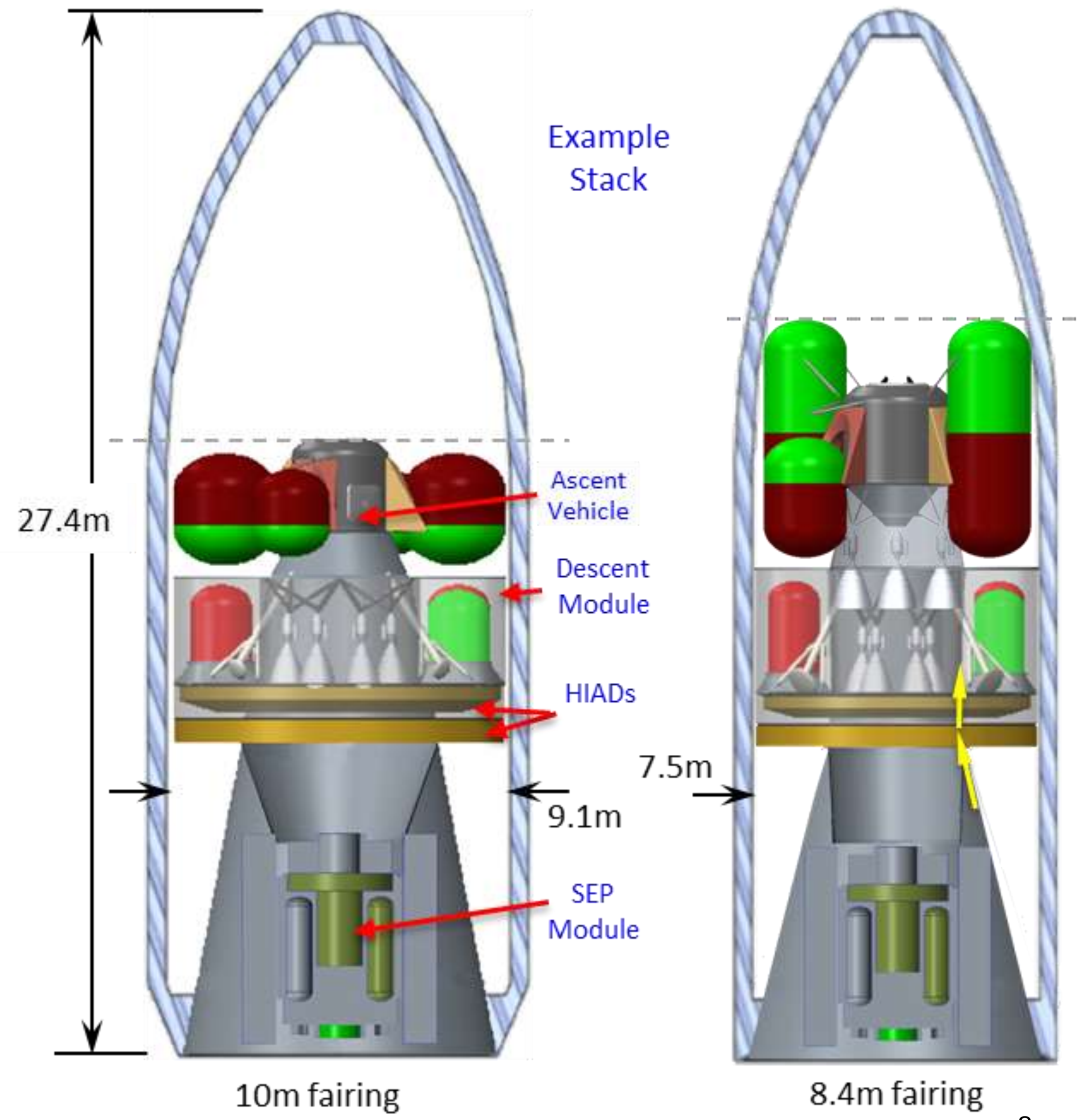


Lander only launch
Then rendezvous
with reusable SEP
hybrid for transit to
Mars

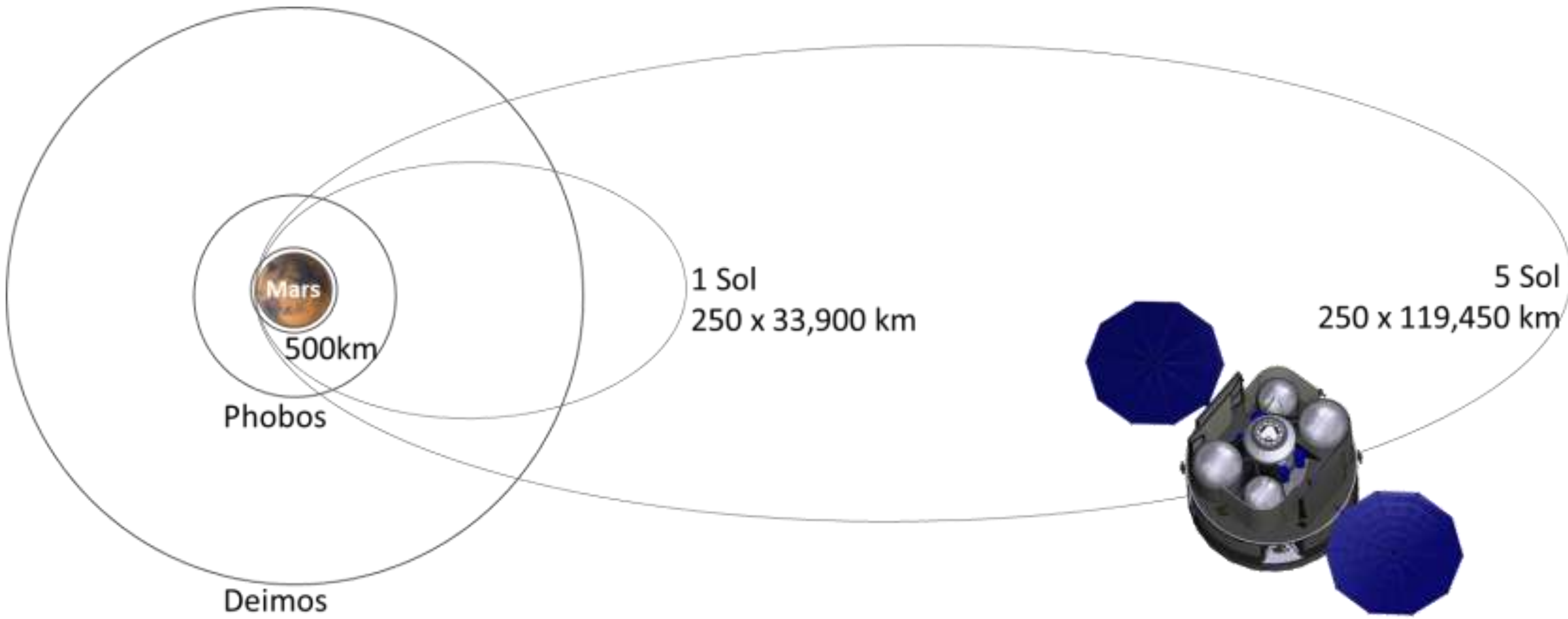
Lander and SEP co-manifested results in greater lander structural mass due to challenge of meeting 5 Hz lat. stiffness goal

Earth Departure Options

- **SLS launch fairing diameters of 10m and 8.4m have been studied**
- **3 of 4 entry system technologies are not likely to be feasible at 8.4m**
- **8.4m fairing challenges mitigated by increasing lander mass and overall architecture risk**
  - *Structures,*
  - *landing gear design,*
  - *stability during entry,*
  - *aft body heating*
- **More landers needed to deliver the same payload**
- ***See paper on this topic***



Mars Arrival Options



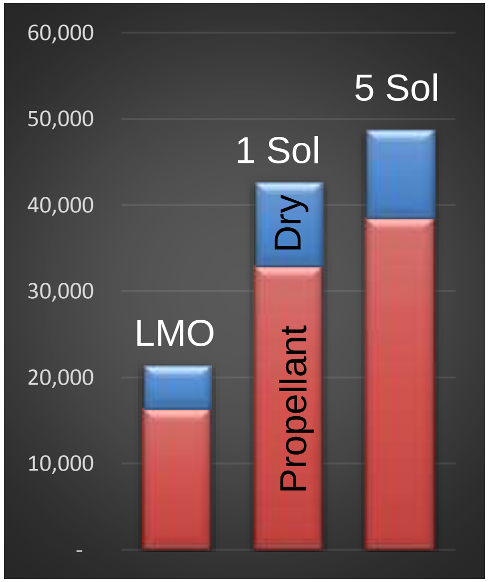
- **Two options for Mars orbit capture were studied**
  - Aerocapture into a 1 Sol orbit, loiter ≤ 1yr, deorbit duration ~12hrs
  - Propulsive Capture using SEP Hybrid into 5 Sol orbit, loiter ≤ 1yr, deorbit duration ~2.5 days

Deorbit from 5 Sol may increase risk of unfavorable landing weather
Aerocapture cases use a 2nd HIAD system to mitigate risk of long exposure during Mars loiter prior to entry.

Entry Descent and Landing Options

- **Sensitivity to payload mass**
  - The greater the payload capability of each lander the fewer number of landers are needed.
    - 4 landers are required with 20mt capability, 3 with 27mt
  - Smaller payload capability results in lighter landers, easier payload packaging and minimum required SEP power levels
  - Payload capability is driven by MAV
    - Ascent to high Mars orbit (1Sol-5Sol) is desired for rendezvous with Earth return vehicle
    - Reliance on ISRU LOX production significantly reduces necessary MAV landed mass (MR > 3 for lox methane)

MAV Mass

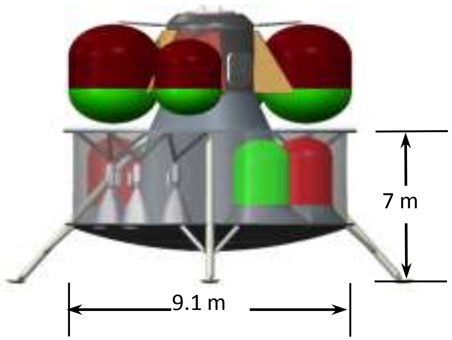


Total Lander Mass (t)= 1.51(payload) + 23.5 Aerocapture
= 1.43(payload) + 18 Propulsive delivery to 5 Sol

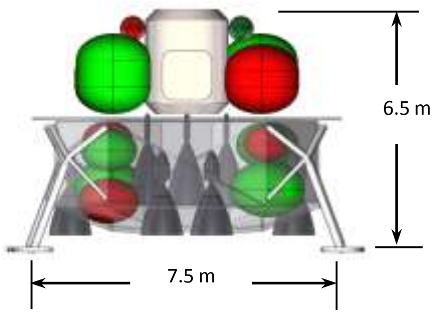
Entry Descent and Landing Options

- **Propulsion Options: Lox/methane vs storable MMH/NTO (both assume pump fed main engines)**
  - Common propulsion technology is assumed for descent and ascent to minimize investments across the architecture
  - Lox/methane + ISRU allows for MAVs to reach high Mars obits while minimizing landed mass to 20mt
  - A storable solution eliminates technology investment in long duration cryofluid management and offers greater packaging density for both descent and ascent stages
  - Storable option must deliver more payload because ISRU MAV propellant production is no longer an option
    - To minimize lander payload delivery requirement, the storable MAV is limited to ascent to a low Mars orbit and the cabin size is minimized to reflect 8-12hr habitation.
    - Requires a new vehicle, Mars orbit taxi, to complete ascent and rendezvous with Earth return vehicle.

Lox/Methane



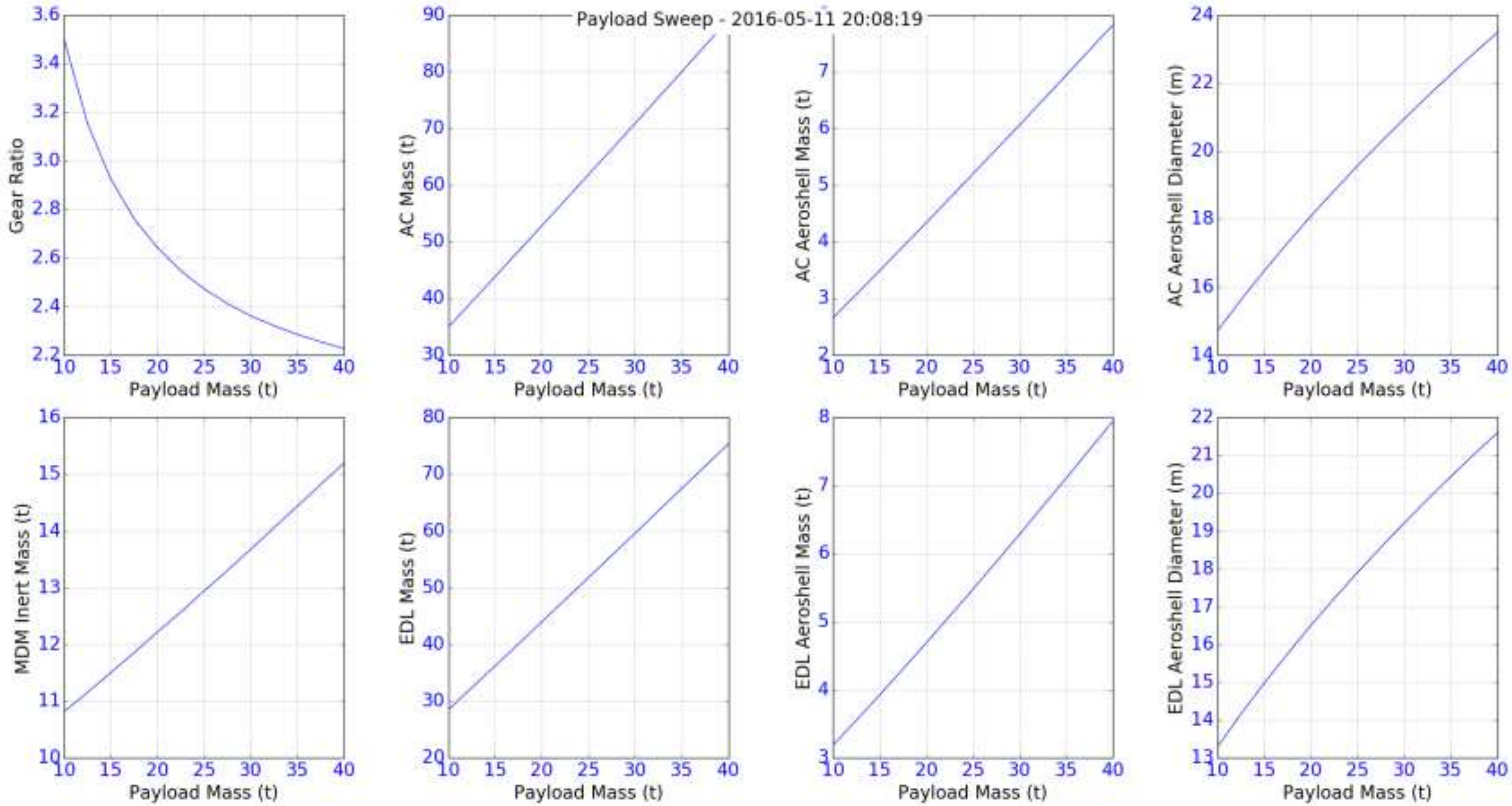
Storable



Results

Component	Masses (kg)					
	Aerocapture to 1 sol Parking Orbit SEP/Chem Split Options			Propulsive delivery to 5 sol Parking Orbit SEP/Chem Hybrid Options		
	27 t LOX/Methane	20 t LOX/Methane	NTO/MMH	27 t LOX/Methane	20 t LOX/Methane	NTO/MMH
Structures	5442	4961	4961	4652	4253	4136
Propulsion	5310	4899	5206	5260	4842	5189
Power	1437	1217	1575	1437	1437	1575
C&DH	136	136	136	136	136	136
C&T	76	76	76	76	76	76
GNC	116	116	116	116	116	116
Thermal	357	328	573	357	328	573
Decelerator	9444	9444	9444	4185	4185	4185
Dry Mass	**22,318**	**21,177**	**22,087**	**16,219**	**15,373**	**15,986**
Cargo	27,000	20,000	23,881	27,000	20,000	24,187
Non-prop Fluids	851	848	951	850	843	920
Inert Mass	**50,168**	**42,025**	**46,919**	**44,068**	**36,216**	**41,093**
Used Propellant	14,093	11,668	12,289	12,519	10,367	11,497
Total Wet Mass	**64,261**	**53,693**	**59,208**	**56,587**	**46,583**	**52,590**

Results



Parametric mass models are in development for all four entry system technologies considered. Models are anchored by point designs generated by multidisciplinary team.

Conclusions

- Landers can be launched alone or co-manifested with SEP stages. however in either case a 10m fairing diameter is desired
- Dual HIADs are assumed for aerocapture options. A single dual use HIAD may be possible but further testing is required
- Lox/methane propulsion + ISRU allows for direct ascent to high mars orbit, while keeping lander payload delivery requirement small
- Storable propulsion options are heavier, require another vehicle to complete ascent, but eliminate need for CFM technology investments
- The HIAD-based Mars lander can accommodate a variety of architecture options.

Questions?