

# Minimalist Human Mars Mission

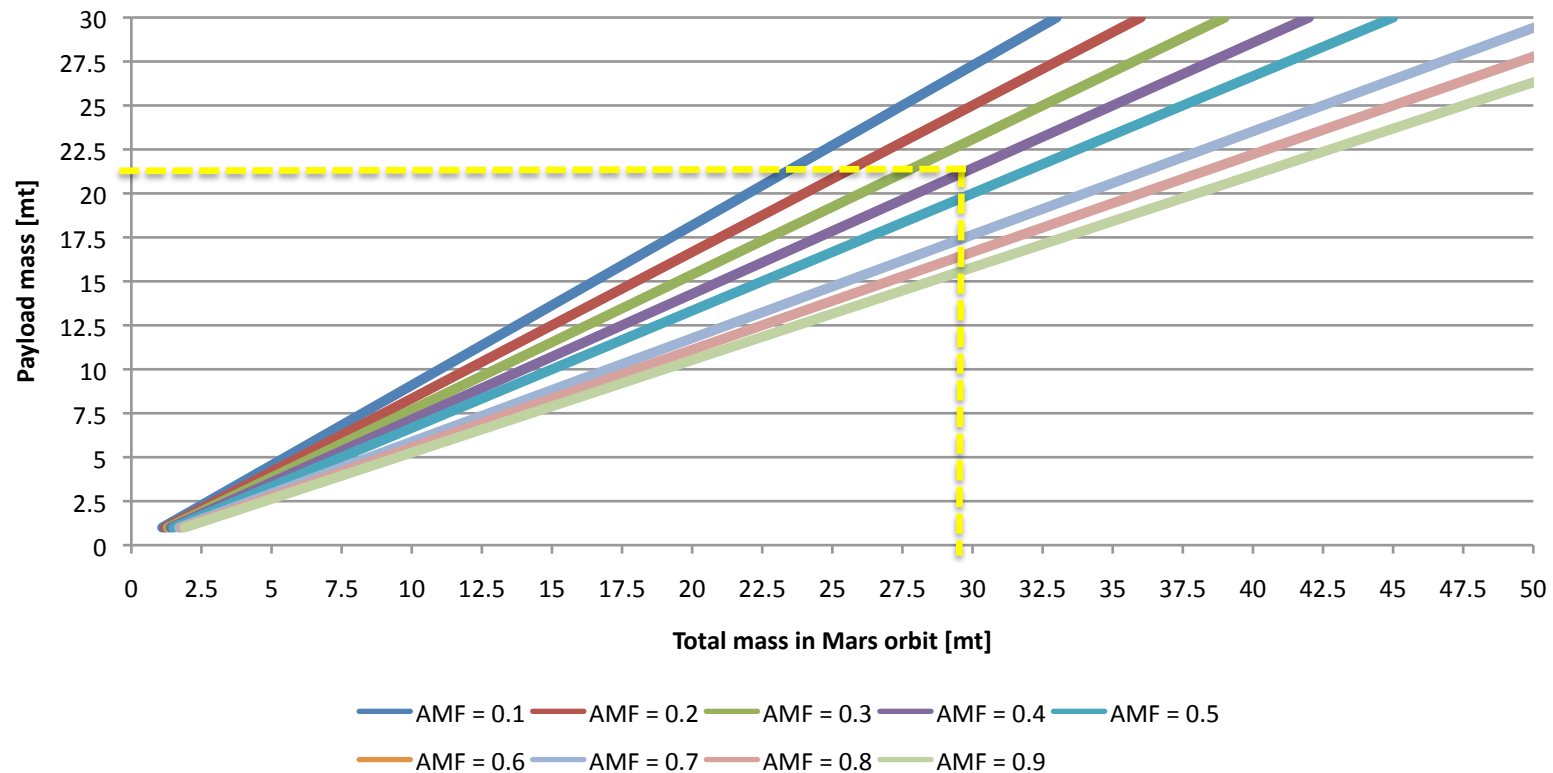
Surface infrastructure discussion

July 26<sup>th</sup>, 2008

# Aeroshell - Mass

- Aeroshell mass set as a fraction of the payload mass (first estimate: AMF = 0.4)
- Total mass set by launch vehicle capability (first estimate: Falcon 9 Heavy = 29,610)
- Based on the above estimates there is 21,150 kg for payload (surface cargo + descent stage)

**Payload mass vs total mass  
for various Aeroshell Mass Fractions (AMF)**

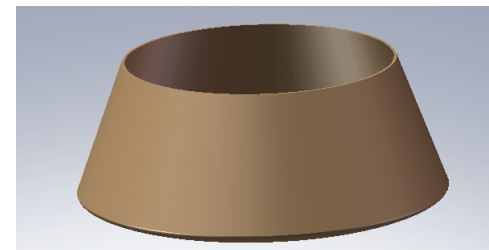


# Aeroshell – Shape & Volume

- Aeroshell shape is estimated to have be a conical frustum with a base diameter of 7.0 m and a height of 6.5 m with a 20° wall angle
- The aeroshell is assumed to be composed of two connected pieces
  - A bottom section with a height of 2.5 m (based on descent engine height) which is jettisoned
    - The useable volume of this section is a cylinder with a diameter of 5.18 m and a height of 2.5 m (52.7 m<sup>3</sup>)
  - A top section with a height of 4.5 m and a base diameter of 5.18 m (usable volume = 47.5 m<sup>3</sup>)
- The total usable volume for the aeroshell is 100.2 m<sup>3</sup>



Top section



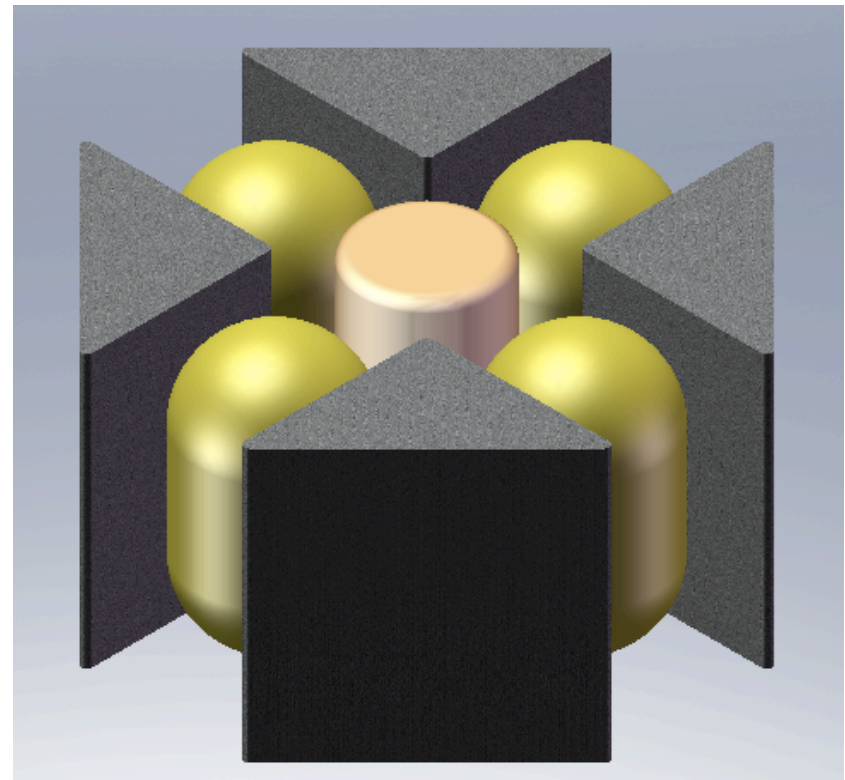
Bottom section

# Descent stage – Mass

- One N2O4-MMH engine based on 26.7 kN OME
  - $I_{sp} = 316$  sec
- Delta-V for terminal descent estimated to be 1200 m/s
- Propellant required = 6,789 kg
- Structural mass fraction for propulsion system = 0.2
  - Note: structural mass fraction is inert mass over propellant mass
- Landing structure is estimated to be 10% of landed mass (approx 1,436 kg)
- These estimates allow for 11,567 kg of surface cargo to be delivered each flight

# Descent stage – Shape & Volume

- One N2O4-MMH engine based on 26.7 kN OME
- Engine envelope of 2.5 m height by 1.5 m diameter
- Two fuel tanks & two oxidizer tanks
  - Cylindrical with semi-spherical end-caps ( $3.0 \text{ m}^3$ )
    - Height: 2.5 m – Diameter: 1.4 m
- Packaged to fit in 5.18 m diameter by 2.5 m height cylinder in lower section of aeroshell
- Initial packaging leaves four “cargo bays” of approximately  $4.0 \text{ m}^3$  each



# MinMars lander cargo capacity

- Top section of aeroshell
  - Conical frustum
    - Available volume: 47.5 m<sup>3</sup>
    - Base diameter: 5.19 m
    - Height: 4.5 m
    - Top diameter: 1.90 m
- Bottom section of aeroshell
  - 4 cargo bays
    - Triangular prism
    - Volume: 4.0 m<sup>3</sup>
    - Base length : 1.79 m
    - Height: 2.5 m

The maximum cargo volume is 63.5 m<sup>3</sup>.  
The maximum cargo mass capacity is 11.57 mt.

Baseline architecture has two lander types:  
(1) Unpressurized cargo delivery (2) Pressurized habitation & logistics modules

# Unpressurized Cargo Lander

- Common descent stage with four cargo bays
- Large unpressurized cargo is placed on top of the descent stage and contained by aeroshell
  - Inflatable habitation modules
  - Surface power systems
  - Pressurized rovers
- Large cargo will require a means of offloading
  - Crane & surface mobility
- How do we remove the top section of the aeroshell?

Example: Flights 1 & 2

<b>Cargo mass available [kg]</b>	<b>Mass [kg]</b>	<b>Volume [m<sup>3</sup>]</b>	<b>Comments</b>
Cargo capacity available	11567	63.5	Top aeroshell section volume + 4 cargo bays
<b>Top section (47.5 m<sup>3</sup>)</b>			
Inflatable module	3100	20	Based on DRM 3.0 (Estimated volume)
Furniture container	1000	10	Estimate
25 kW surface power system (PV+Li-ion)	2273	14	Estimate based on 11W/kg
<b>Cargo bay 1 (4.0 m<sup>3</sup>)</b>			
Unpressurized rover	550	3	Based on DRM 3.0
<b>Cargo bay 2 (4.0 m<sup>3</sup>)</b>			
Large element mobility	1000	3	Estimate
<b>Cargo bay 3 (4.0 m<sup>3</sup>)</b>			
Unloading equipment	550	3	Estimate
<b>Cargo bay 4 (4.0 m<sup>3</sup>)</b>			
Construction equipment	1000	3	Estimate
<b>Total cargo</b>	<b>9473</b>		

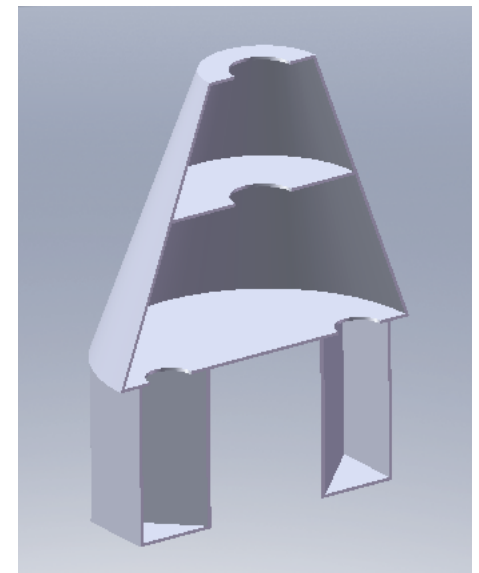
# Common Pressurized Module

- Concept: Use a common module for all habitation (hab, lab, workshop) and pressurized logistics delivery and add in necessary subsystem hardware to adapt each module to its needs
- This concept may allow reuse of logistics modules as “hotel rooms” and eliminate the need for early inflatable modules (low TRL)
- With large element surface mobility that is capable of transporting landers (over prepared ground) to allow connection between units would be beneficial



# Initial habitat concept

- Two floor habitat integral with top section of the aeroshell
  - Main floor is 2.5 m high with a floor area of 21 m<sup>2</sup> (226 ft<sup>2</sup>)
  - Top floor is 2.0 m high with a floor area of 8.9 m<sup>2</sup> (96 ft<sup>2</sup>)
  - Two floor are connected through a 1 m diameter tunnel in the middle of the floor
- Habitat is connected to two “airlocks” which replace two cargo bays in the descent stage
  - Triangular prisms with a volume of 4m<sup>3</sup>



# Initial subsystems

- Structures: 2400 kg
  - Based on surface area and area density from DRM 3.0 (21 kg/m<sup>2</sup>)
- Life support systems: 316 kg
  - Based on two crew and HSMAD hardware for Wilfried's architecture
- Comm-info management: 320 kg
  - Taken from DRM 3.0
- Thermal: 184 kg
  - Based on two crew and scaled from DRM 3.0

**Total mass of generic pressurized element = 3220 kg**  
**Cargo capacity remaining on lander = 8347 kg**

# Logistics flights

- Pressurized logistics: 4000 kg (2 crew)
  - Estimated volume: 13-16 m<sup>3</sup>
  - Note: Usable volume on top floor is 9.6 m<sup>3</sup>
- Unpressurized cargo: 1000 kg (spares, etc.)
  - Volume available is 4 m<sup>3</sup>
- Furniture and interior furnishings: 2000 kg
  - Estimate (Cal Tech MSM estimated 1000 kg)
  - As logistics are used / moved (to other modules upper storage sections) habitat becomes available as living space
- Flights 3 & 4 (opportunity 2) can be used as logistics flights and provide two 2-person habitats

# Crew flights (1/2)

- Two concepts:
  - Identical habitats with all required crew accommodations in each (for two crew)
  - One habitat (galley, wardroom, hygiene) & one laboratory (medical, maintenance, etc)
- First concept has each aeroshell pushed separately to Mars using two TMI stages each
- Second concept has the crew join up and travel to Mars in two connected aeroshells
  - Crew all lands in habitat
- In space power stage will be needed for transit to Mars
  - Either one or two depending on concept
- Consumables for trip (4.5 kg/p/d for 210 days) total 3.78 mt and 12.5 – 15 m<sup>3</sup>
  - Can be stored in upper level storage area and used consumables can be jettisoned before entry to Mars
- “Airlocks” can be modified for the trip to provide four private quarters with 4 m<sup>3</sup> each.

# Crew flights (1/2)

- Based on HSMAD, crew accommodations system hardware require ~2.9 mt for two crew
- On Mars surface, top floor used for logistics storage, main floor for common area
  - Private quarters are set up in logistics modules
  - Is 21 m<sup>2</sup> of floor space on the main floor enough for all common crew systems (galley, hygiene, operations, etc.)?
- At Martian surface, crew will remain in habitat for ~7 days to acclimatize.
- Then use unpressurized rovers (one per habitat in cargo bay) to transit to pre-positioned goods and work to set up base
- Note: How do we supply surface power to Habitats before 25kW pre-positioned systems are connected?

# Other thoughts

- Inflatable modules may not be required on first flights
  - Replace with pressurized mobility?
  - Currently have 4 unpressurized rovers manifested
    - One on each cargo flight
    - One on each crewed flight
- With four crew and a consumables requirement of 2 mt /opportunity/person:
  - Each of the following opportunities will require both flights to be logistics modules
  - Logistics modules could be adapted to be workshops, laboratories, etc. using the 2 mt set aside for furniture

# Notional Flight Manifest

- Opportunity 1 (identical flights)
  - 1 pressurized rover
  - 1 unpressurized rover
  - Surface power systems
  - Offloading hardware and large element mobility
- Opportunity 2 (identical flights)
  - Pressurized module
  - Furniture to adapt to living quarters for two crew
  - Pressurized logistics
  - Unpressurized logistics
- Opportunity 3 (crew)
  - One habitat (common area for four crew) flight
  - One laboratory / medical / exercise flight
  - 2 unpressurized rovers
- Opportunity 4+ (two identical flights)
  - Pressurized module
  - Pressurized logistics
  - Unpressurized logistics
  - How are these adapted?

# Tasks for next telecon

- Detail equipment in and layout of initial four pressurized modules
  - Furniture required for adapting logistics modules
  - Systems for common habitat
  - Systems for common laboratory
- Detail offloading and element transportation scheme
  - How to offload pressurized rovers/surface power systems
- Illustrate base build-up
- Outline surface mobility capabilities
  - Unpressurized rovers: single person ATVs with capability of carrying two crew
  - Pressurized rover concept