Human Mission to Mars

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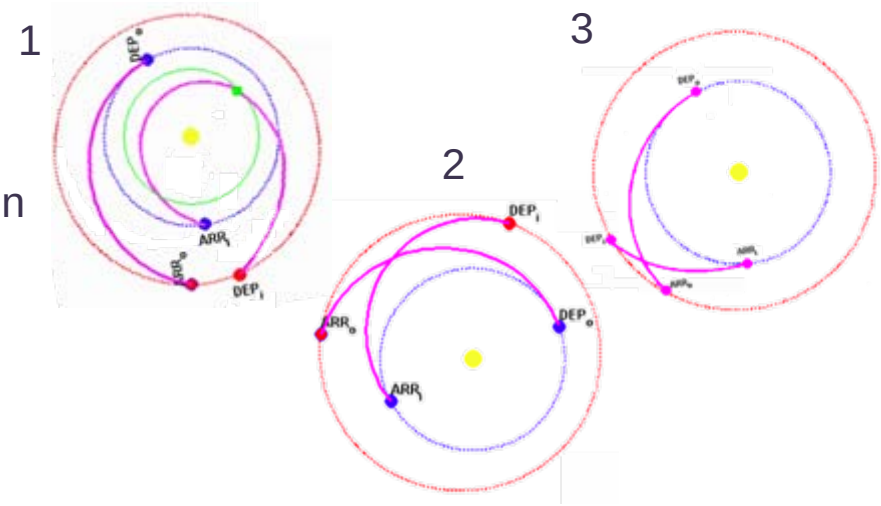
Analyzed Options

Mission Strategy

Considered Options:

1. Short stay Mission
2. Long stay, Minimum energy Mission
3. Long stay, Fast transit Mission



Flight Strategy

Considered Options:

- Altogether
- Split

Propulsion Technology

Considered Options:

- Chemical
- Solar Electric
- Nuclear Thermal
- Nuclear Electric

Departure Orbit

Considered Options:

- LEO
- Lagrangian Point 1

Crew Size

Considered Options:

- 4 crew members
- 6 crew members

Surface Extended Mobility

Considered Options:

- Available
- Not available

In-Situ Propellant Production

Considered Options:

- Available
- Not available

Selected Options

Team	Red	Blue	
Stay Duration at Mars	Long Stay		
Flight Strategy	Altogether	Split	
Departure Orbit	L1	LEO	
Departure Propulsion	Solar Electric	Nuclear Thermal (M)	Nuclear Thermal (C)
MOI Propulsion	Solar Electric	Nuclear Thermal (M)	Aerocapture (C)
Return Propulsion	Solar Electric	Nuclear Thermal (M)	None (C)
Crew Size	6		
Surface Extended Mobility	No		
In Situ Propellant Production	No		

M = Manned C = Cargo

Chemical vs. Nuclear Options

Type of mission	Cargo	Manned	Total	
Scenario1 (All Cryo)	3 x HLLV (350 t) + 3 x HLLV (350 t)	4 x HLLV 1 AR5 ESC-B 1 x Manned (530 t)	10 x HLLV 1 AR5 ESC-B 1 x Manned (1230 t)	
Scenario2 (Storable TEI)	3 x HLLV (350 t) + 3 x HLLV (350 t)	6 x HLLV 1 x Manned (760 t)	12 x HLLV 1 x Manned (1460 t)	
Scenario3 (Nuclear)	2 x HLLV (250 t) + 2 x HLLV (250 t)	2 x HLLV 1 x Manned (275 t)	6 x HLLV 1 x Manned (775 t)	

To permit comparisons between nuclear and chemical scenario's the payload considered are the same in all the scenario's

The LMO injection for the cargo missions would be obtained via aerocapture in Mars atmosphere

Solar Electric Propulsion

The requirements of the human mission to Mars are the following:

- Assembly of Mars Transfer Vehicle in EML1
- Electrical thrusters for transfer stages to Mars and back to EML1
- Transfer from Earth to EML1 and back to Earth by chemical propulsion stages
- Chemical propulsion for Mars descender and ascender from 500 km Mars circular orbit
- Stay time on Mars surface of 230 days
- Transportation of a crew of 4 to Mars surface and back to Earth

Transportation Elements

- Electrical Transfer Stage TMI, MOI, TEI and L1-Injection
- Transfer Habitat
- Surface Habitat
- Rover, Power plant,etc..
- Mars ascender
- Mars descender

In total are foreseen 2 flights with the reusable electrical transfer vehicle

- First flight with Descender+Surface Habitat, Descender+Rover/Power-Plant and the EP Transfer Vehicle Total Mass: 240 t
- Second flight with Transfer Habitat, Descender+Ascender and EP Transfer Vehicle Total Mass: 335 t

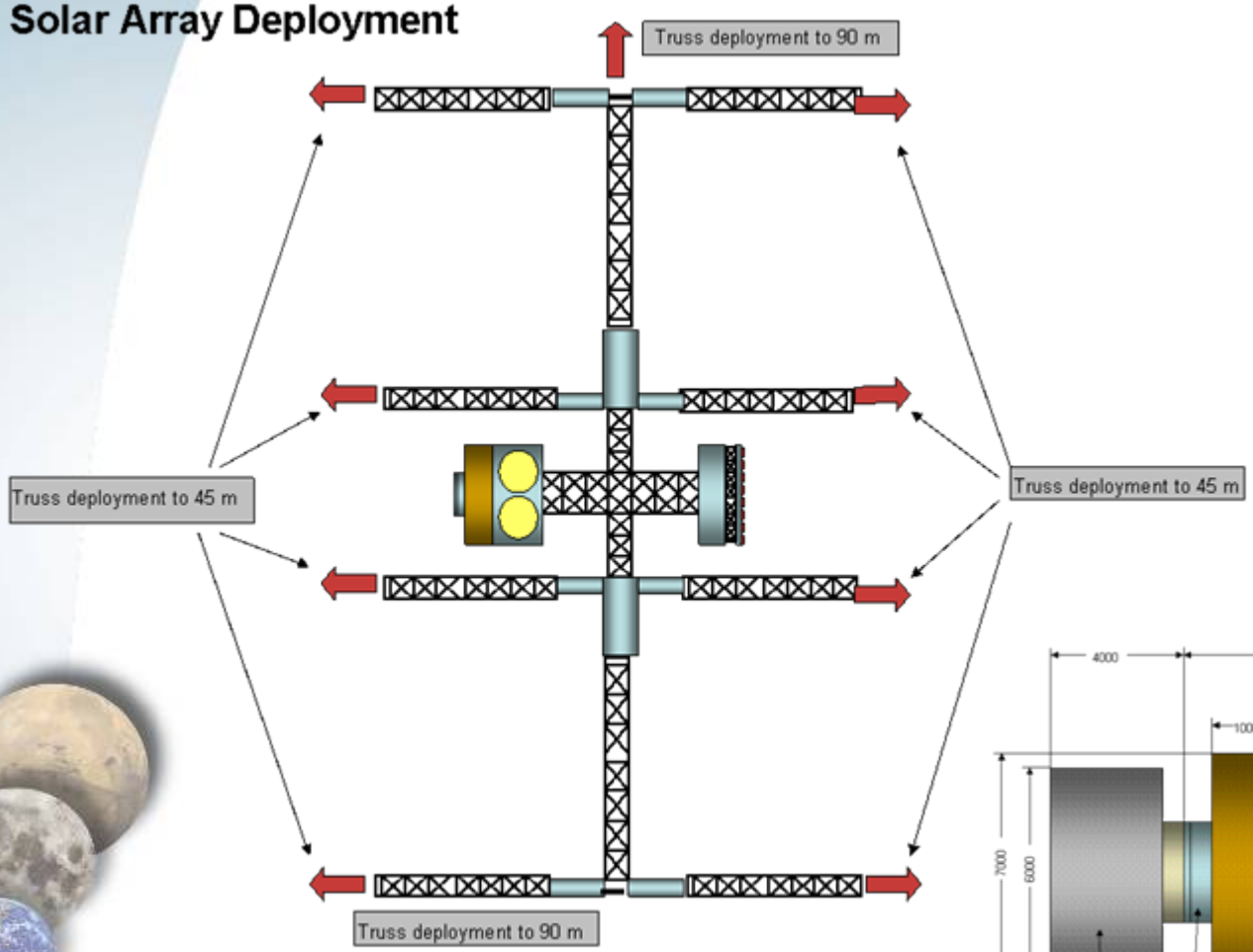
Needed launches:

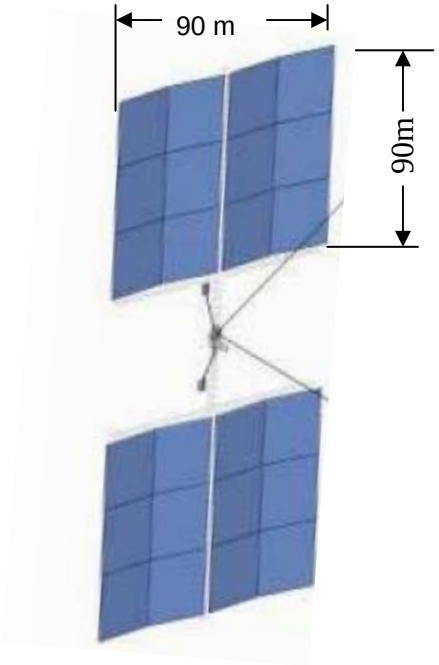
- 10 Ares V plus 1 Ariane 5 ESC-B to complete the manned spacecraft
- 7 Ares V plus 1 Ariane 5 ESC-B to refurbish the second mission

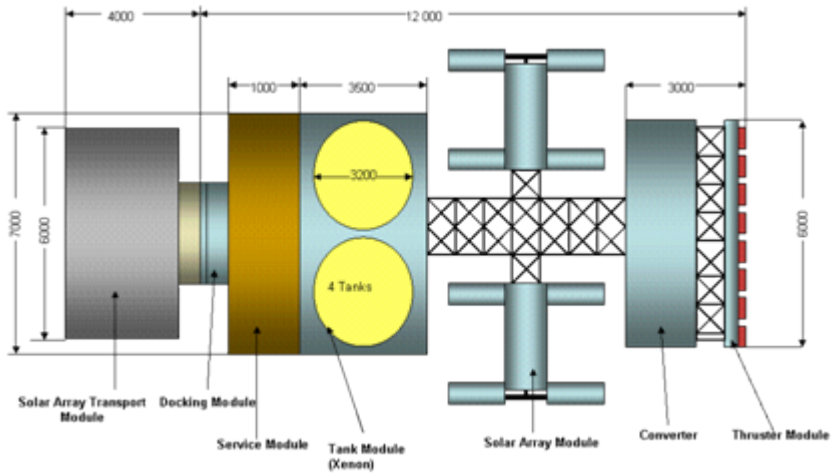
A total of 17 Ares V plus 1 Ariane 5 ESC-B launches needed to perform the manned mission to Mars

Mars SEP Spacecraft Configuration

Solar Array Deployment







Manned Mission

Nuclear Propulsion

Cargo Missions Overview

First Cargo Mission

Objective: Transport the Surface Habitat, the Nuclear Power Plant and the Transportation Vehicle to the Mars surface

Second Cargo Mission

Objective: Transport to LMO the Ascent/Descent Vehicle and to the Mars surface the Pressurized Rover, the ISRU Plant and additional equipments.

Available launchers: Ares V, Ariane 5 ESC-B

Transportation Segment Elements: Mars Transfer Stage 1 (MTS1), Lander 30 T, Lander 23T, Payload Tug, LEO Tug

LEO activities:

- Docking/Berthing with the LEO Assembly Station
- Mars Spacecraft Assembly

Mission profile:

- Approach with the LEO Assembly Station
- Mars Spacecraft orbit raise
- TMI Maneuver
- Mars Aerocapture
- Descent and Landing

Needed Launches
2 + 2 x Ares V

Manned Mission Overview

Objective: Transport the crew to the Mars surface and back to Earth

Available launchers: Ares V, Ariane 5 ESC-B, Ares I

Transportation Segment Elements: Mars Transfer Stage 1 (MTS1), Mars Transfer Stage 2 (MTS2), Lander 30 T, Payload Tug, LEO Tug, Orion Capsule, Mars Ascent Stage

LEO activities:

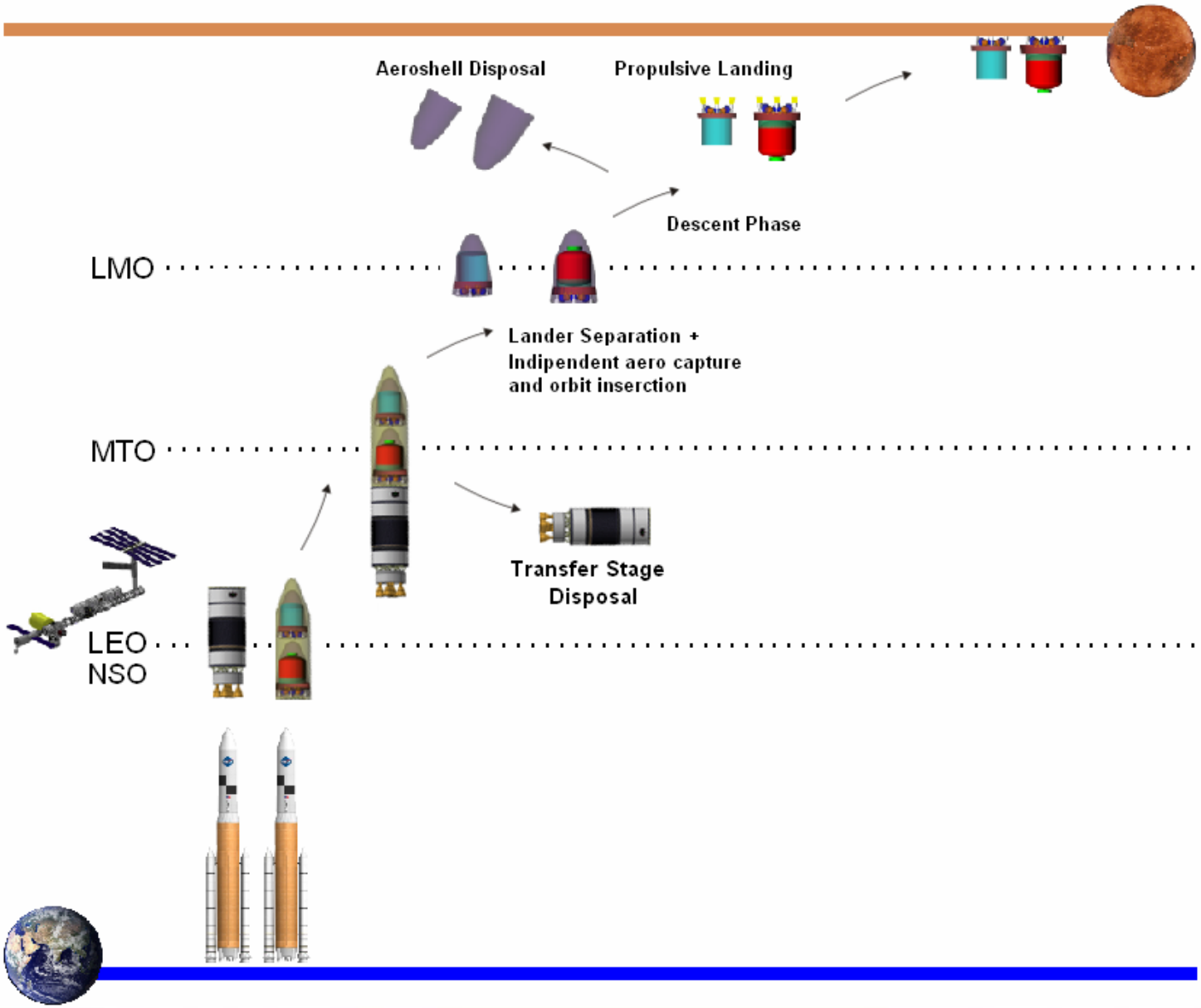
- Docking/Berthing with the LEO Assembly Station
- Mars Spacecraft Assembly

Mission profile:

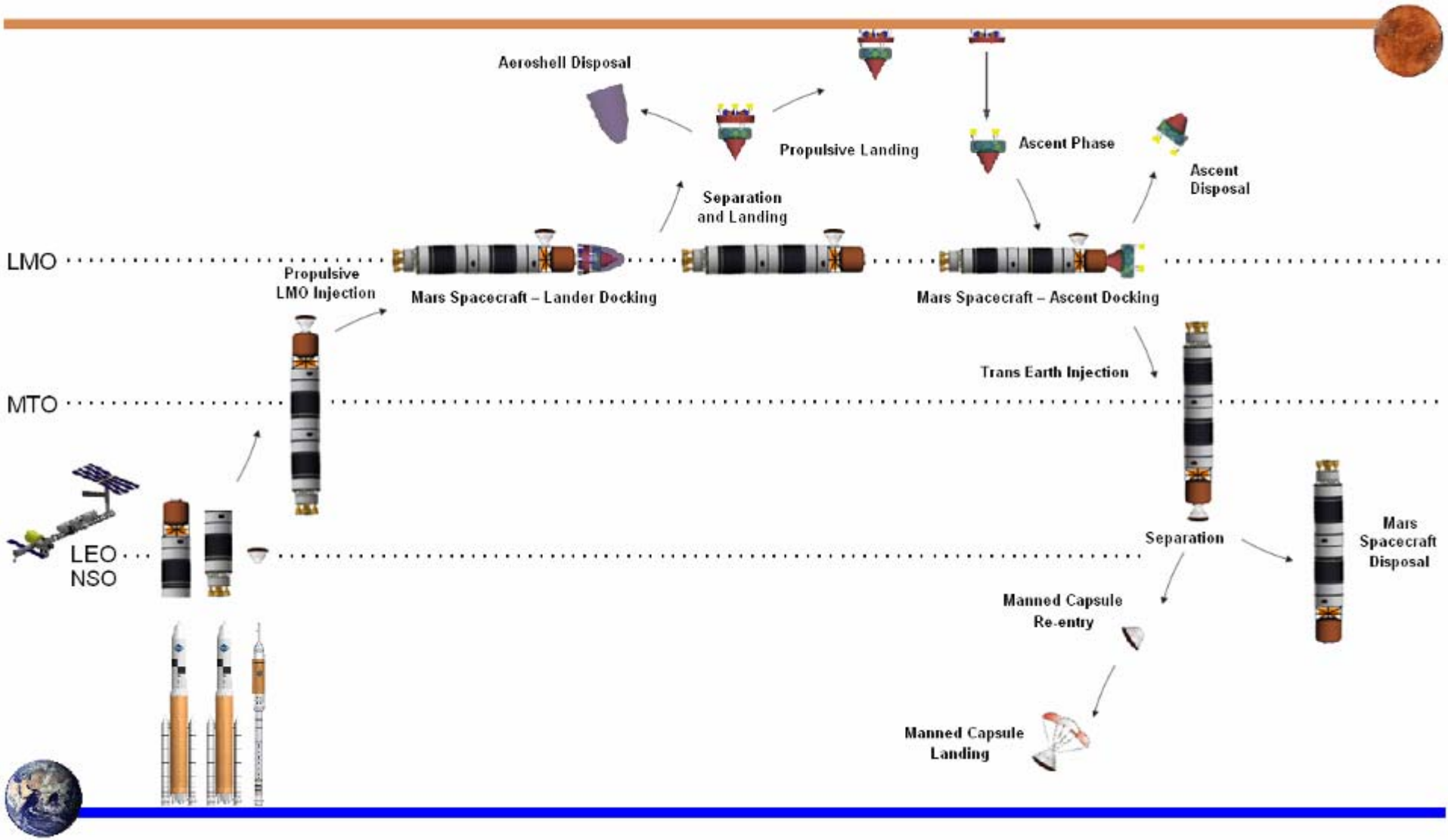
- MTS Approach with the LEO Assembly Station
- Mars Spacecraft orbit raise
- Crew Capsule R&D with the Mars Spacecraft
- TMI and LMO Injection Maneuvers
- Mars Spacecraft R&D with the Mars Ascent Stage
- Descent and Landing
- Ascent, R&D with the Mars Spacecraft
- MAS Disposal and TEI Maneuver
- Capsule Re-entry and Mars Spacecraft Disposal

Needed Launches
2 x Ares V
1 x Ares I

Cargo Mission



Manned Mission



Mars Architecture Elements

LEO Assembly Station

Main Functions:

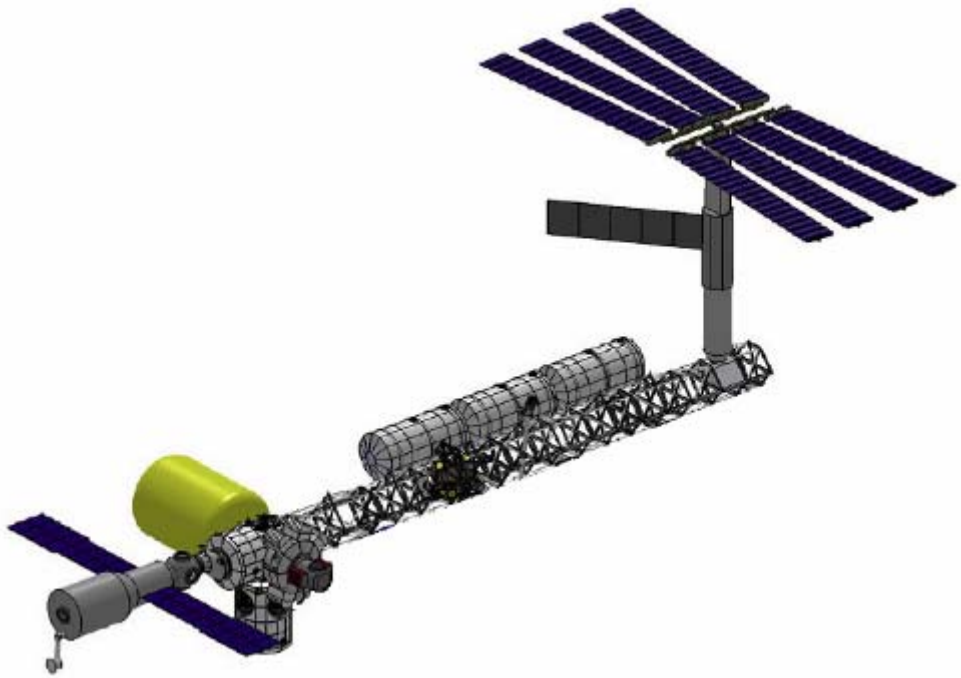
- Support the partial assembly in LEO of the Mars exploration vehicles
- Provide robotic support to the assembly operations
- Act as waiting point for the different elements during the integration process
- Provide power to the different elements during the integration process
- Provide re-fueling capabilities

Foreseen Elements:

- Habitation Module
- Solar Panels
- Robotic Assembly Facility
- Service Module
- Crew Rescue Vehicle
- Cryogenic Facility
- Airlock
- Node

Dimensions:
Length: ~ 45 m
Overall Mass: ~ 150 mT

Operative life: about twenty years



Mars Transfer Habitat Module

Main Functions:

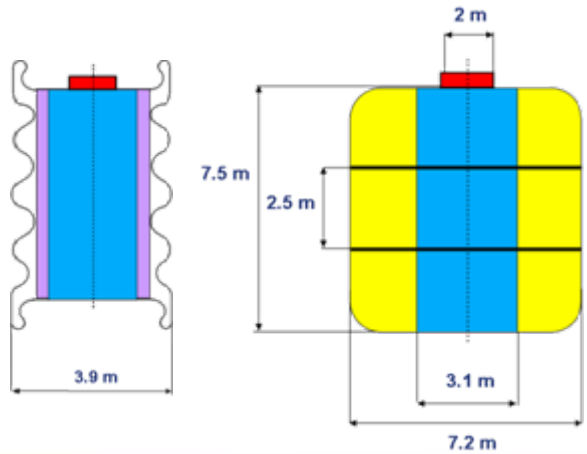
- To provide a pressurized volume of at least 75 cubic meter per crew member
- To provide a shirt sleeve environment for the crew
- To provide consumables according to the ECLSS configuration chosen;
- To provide a protection from Galactic Cosmic Rays and Solar Particle Events

Characteristics:

- Totally open loop for the food to assure a higher level of safety with a lower cost
- Atmosphere composition is closed to the Earth condition at the sea level (79% N_2, 21% O_2)
- Resources for 500 days (~ 7.900 kg) (nominal scenario)
- Spare resources for 500 days (~ 7.900 kg) (contingency)

Launch configuration

Deployed configuration



Dimensions:

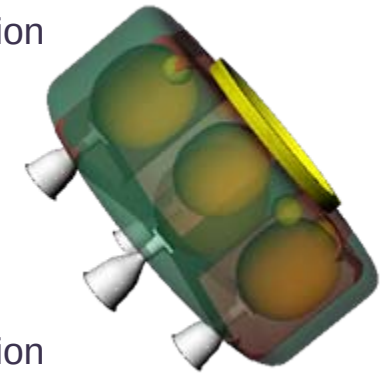
Stowed Diameter: ~ 3.9 m
Inflated Diameter: ~ 7.2 m
Length: ~ 7.5 m
Overall Mass: ~ 22600 kg

Operative life: about three years

LEO & Payload Tug

LEO Tug Main Functions:

- To ensure a 400 km LEO perigee raise boosting a payload of about 240 tons
- To return autonomously to the LEO assembly station
- To perform the needed docking operations with the LEO assembly station
- To have a refuel capability
- To assure a reusability up to TDB times



Payload Tug Main Functions:

- To approach autonomously the LEO assembly station
- To perform the needed docking operations with the LEO assembly station
- To perform a destructive re-entry in the Earth atmosphere

Main Propulsion:
Selected Propellant: LH2/LOx
Selected Engines:

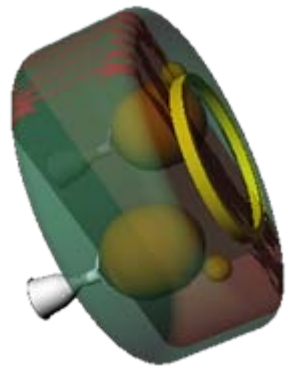
- LEO Tug: 4 Vinci
- Payload Tug: 2 Vinci

Engine Isp: 460 s

Attitude Control System:
Selected Propellant: Bipropellant MON/MMH
Selected Engines: 24 RCS Thrusters

LEO Tug Dimensions:
Diameter: ~ 8.8 m
Length: ~ 4.3 m
Overall Mass: ~ 22000 kg

Payload Tug Dimensions:
Diameter: ~ 8.8 m
Length: ~ 4.3 m
Overall Mass: ~ 5800 kg



Mars Transfer Stage 1

Main Functions:

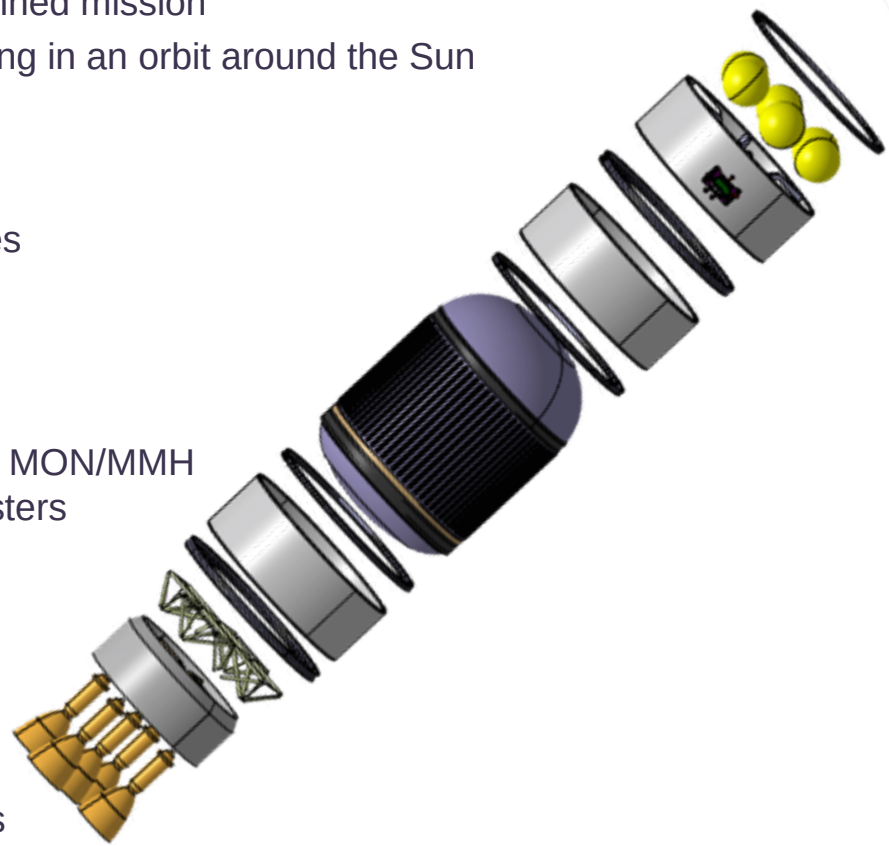
- To provide the thrust required to perform the Trans Mars Orbit Injection in both the cargo and the manned mission
- To provide the thrust required to perform the Mars Orbit Injection and the Trans Earth Orbit Injection in the manned mission
- To perform the disposal inserting in an orbit around the Sun

Main Propulsion:
Selected Propellant: LH2
Selected Engines: 5 NTR Engines
Total Thrust: 333.5 kN
Engine Isp: 1000 s

Attitude Control System:
Selected Propellant: Bipropellant MON/MMH
Selected Engines: 24 RCS Thrusters

Dimensions:
Diameter: ~ 10 m
Length: ~ 29 m
Overall Mass: ~ 119000 kg

Operative life: about three years



Mars Transfer Stage 2

Main Functions:

- Provide the supplementary fuel necessary to perform the additional propulsive injections required by the manned mission
- Collaborate to the attitude and orbital control with the MTS1

Tank:
Selected Propellant: LH2

Tanks capability 63200 kg total

Dewar tank

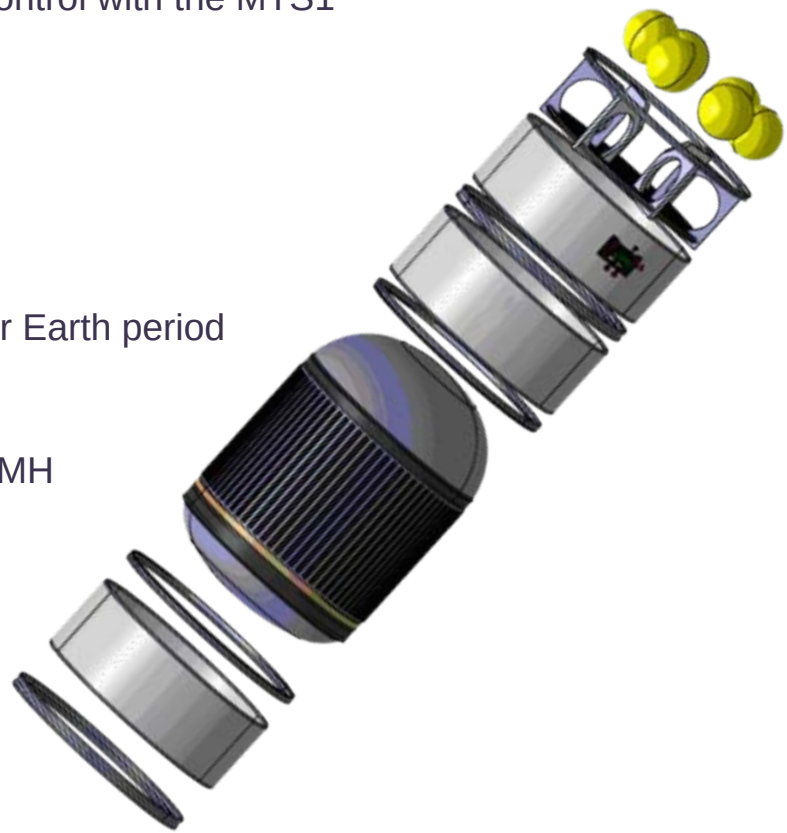
Insulated using MLI for on orbit period

Closed-cell sprayed-on foam insulation for Earth period

Attitude Control System:
Selected Propellant: Bipropellant MON/MMH
Selected Engines: 24 RCS Thrusters

Dimensions:
Diameter: ~ 10 m
Length: ~ 22 m
Overall Mass: ~ 80000 kg

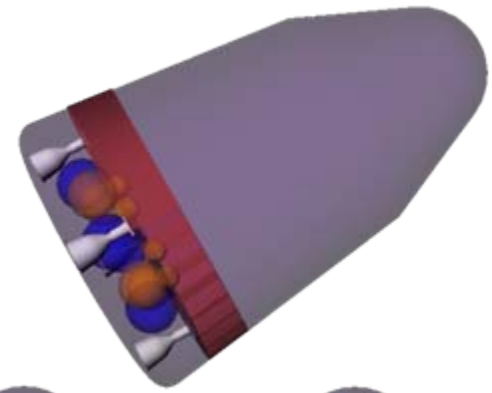
Operative life: 6 month



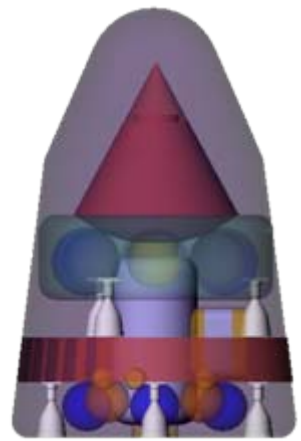
Mars Exploration Landers – 30T & 23T

Main Functions:

- To land cargo and manned elements, having a maximum mass of 31.5 mT, to the Mars Surface
- To allow a safe entry in the Mars atmosphere
- To accommodate in their cargo bays different payload typology
- To assure the utilization in both the cargo and the manned missions
- To exploit as much as possible the design commonalities



Main Propulsion:
Selected Propellant: LOX/CH4
Selected Engines: 4 RL10-class engines
Total Thrust: 266.8 kN
Engine Isp: 379 s



Attitude Control System:
Selected Propellant: Bipropellant MON/MMH
Selected Engines: 24 RCS Thrusters

MEL-30T Dimensions:
Diameter: ~ 8.8 m
Length: ~ 13.1 m
Overall Mass: ~ 25400 kg

Operative life: about three years

MEL-23T Dimensions:
Diameter: ~ 7.8 m
Length: ~ 11.5 m
Overall Mass: ~ 18600 kg

Operative life: about 1.5 years

Mars Ascent Stage

Main Functions:

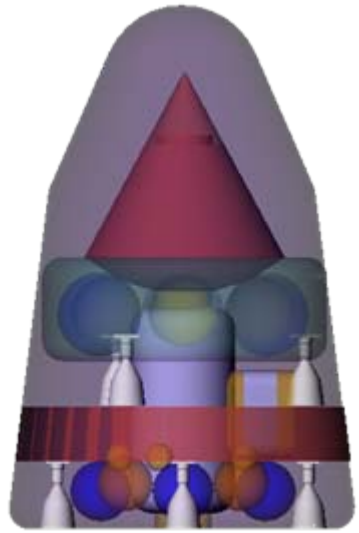
- To ensure a crew of four survival condition on each mission phases (LMO-MS descent phase, 15 days permanence on the MS and the MS-LMO ascent phase & docking)
- To allow the crew sortie on the Mars Surface
- To perform the crew ascent from the MS to the LMO
- To allow the crew transfer from the Mars Transfer Habitat Module to the MAS and vice versa
- To assure a pressurized volume in which two crew members could perform the EVA suit wearing operations

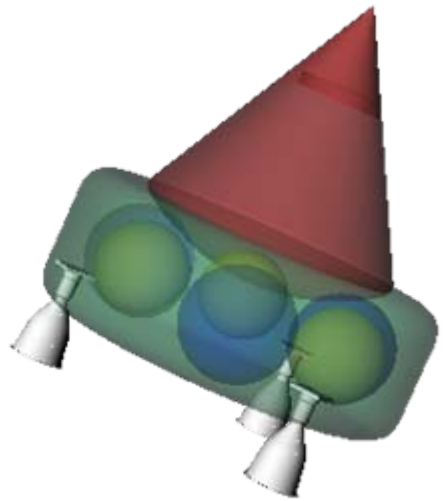
Main Propulsion:
Selected Propellant: LOX/CH4
Selected Engines: 3 RL10-class engines
Total Thrust: 200 kN
Engine Isp: 379 s

Attitude Control System:
Selected Propellant: Bipropellant MON/MMH
Selected Engines: 24 RCS Thrusters

Dimensions:
Diameter: ~ 7 m
Length: ~ 8.4 m
Overall Mass: ~ 31500 kg

Operative life: about 3 years





Mars Surface Habitat

Main Functions:

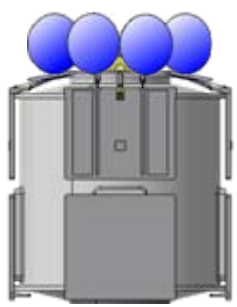
- To sustaining the life of four astronauts on the Martian surface, providing resources and equipment for the foreseen stay period (up to 200 days for the Red Team, up to 500 days for the Blue Team).

Red Habitat
Inflatable technology foreseen to meet both the habitability req's and the lander constraints

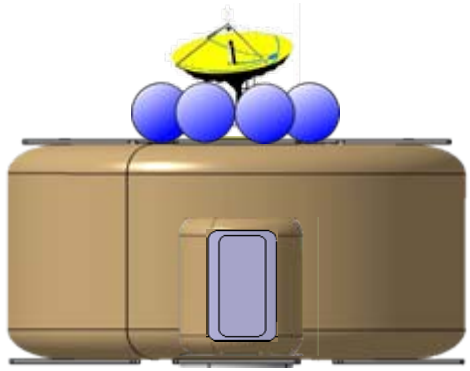
ECLSS based on:
- WPA (no UPA)
- 4 Bed Molecular Sieve
- CO_2 vented, no regeneration of O_2

Dimensions:
Diameter: 10 m (Stowed: ~ 4.5 m)
Height: ~ 4 m
Pressurized Volume: ~ 300 m^3
Overall Mass: ~ 31500 kg
Max Power consumption: 22.8 kW

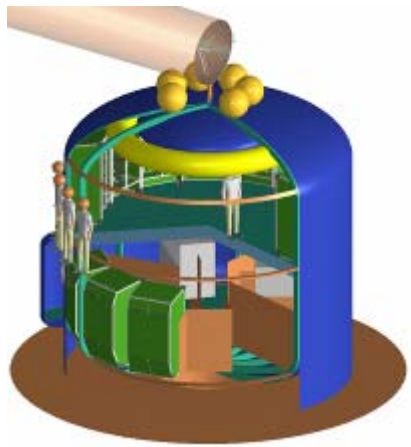
Blue Habitat Dimensions:
Diameter: 6.4 m
Height: ~ 6.4 m
Pressurized Volume: ~ 200 m^3
Overall Mass: ~ 31500 kg
Max Power consumption: 30 kW



Stowed Configuration



Inflated Configuration



Blue Habitat Configuration

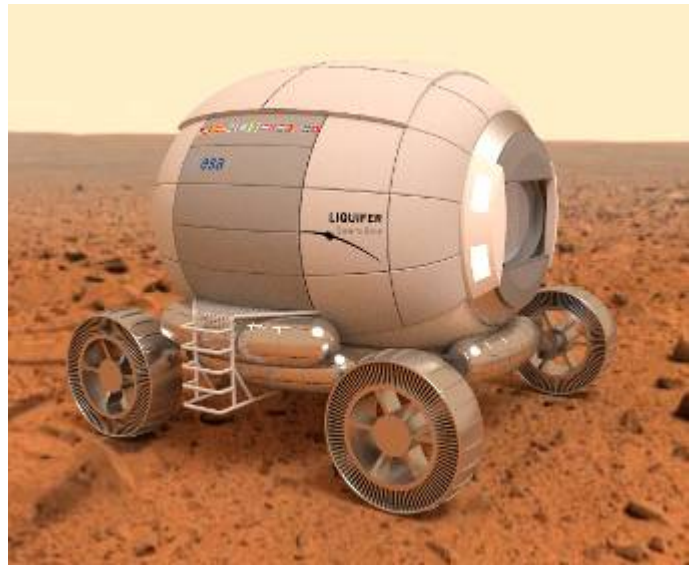
Pressurised Rover

Main Functions:

- To support a crew of two people throughout the duration of the surface mission (20 days before re-supply)
- To allow the crew sortie on the Mars Surface
- To cross the lunar or Martian landscape (up to 1600 km) at a maximum speed of 15 km/h
- To climb slopes with gradients of up to 20 degrees, if necessary at a reduced speed
- To be operated by crew members or remotely from either a ground control centre or Mars base

System performances:

- Total duration of Mars surface mission 20 days
- Time spent traversing the surface 10 days driving 8 hours per day at a speed of 10 km/h
- Time spent at exploration site 10 days



EVA Strategy

- One EVA per person at intervals of not less than 3 days
- Two suitports for new EVA suit concept

Dimensions:

Height: ~ 3.4 m
Length: ~ 5.4 m
Internal Volume: 40 m^3/person
Overall Mass: ~ 9000 kg

Capability requirements

Required Technologies and capabilities:

Transportation and Propulsion:
- Nuclear Thermal Engines
- Advanced Electric Engines
- Cryogenic Fluid Management Technology
- Advanced Heat Shield Technology
- Precision Landing Capabilities
- Heavy Lift Launch Vehicles

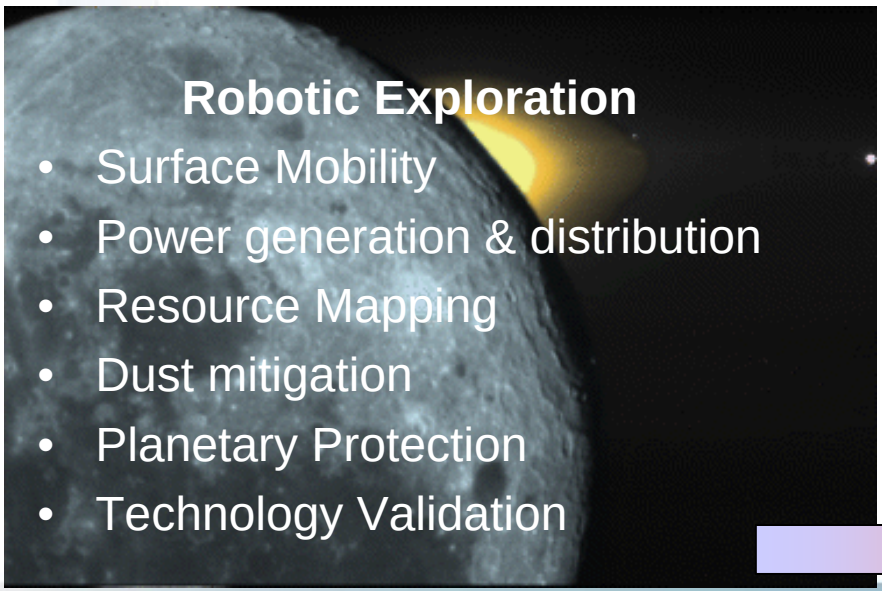
Power & Thermal:
- High-efficiency energy conversion systems
- High-temperature energy conversion systems
- Advanced Radiators

Human aspects:
- New Concept EVA suits
- Lightweight Radiation Protection Systems
- Improved ECLS Systems

Robotics:
- Advanced RVD Systems
- Autonomous ISRU Systems
- On orbit systems construction facilities

Moon and Mars Synergies

What can we learn by exploring the Moon before embarking people to Mars?



Robotic Exploration

- Surface Mobility
- Power generation & distribution
- Resource Mapping
- Dust mitigation
- Planetary Protection
- Technology Validation

Human Exploration

- Advanced Mobility (Pressurised Rovers)
- Protection from Environment
- Radiation protection
- Space weather prediction
- New generation EVA suits
- Operations beyond LEO
- Long duration missions
- In-Space Assembly
- Surface Pressurised Elements (Rigid & Inflatable)
- CELSS