Mars ISRU Habitat

Project Athena - Operations & Overview

Cargo MTV Assembled In Orbit

13 SLS Launches + 5 for re-fueling

Earth Orbit

Human MTV Assembled In Orbit

16 SLS Launches

Departure: 25/11/2028

1 — 300 Days

3 — 220 Days

4 — 200 Days

Arrival: 03/05/2040

7 — 198 Days

10 — 286 Days

Mars Orbit

2

5

8

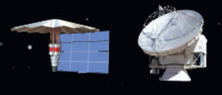
Sequence of Events

1. Cargo MTV travels to Mars orbit from LEO
2. Rovers and support payloads landed
3. Cargo MTV returns from Mars orbit to LEO
4. Cargo MTV is re-fueled and re-stocked in LEO
5. Internal habitat payload delivered and cargo MTV decommissioned
6. Habitat moved to site by rovers
7. Human MTV travels to Mars orbit from LEO with 4 astronauts
8. Humans land on Martian surface from Mars orbit with the MDV
9. Internal habitat set up and scientific stay begins for 465 days
10. Astronauts return to Human MTV in Mars orbit using MAV, Human MTV returns to Earth

In-Situ Construction Phase-1463 Days

Communication, Power and ISRU Processing Plants Deployed

3



Robotic Construction

Regolith Excavated

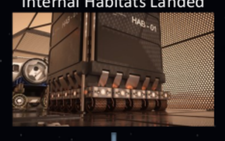
Sintering Processes

Completed Regolith Shell

Crewed Construction Phase

6

Internal Habitats Landed



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Internal Habitats Inflated

Internal Habitats Moved to Shield

Full Internal Habitat Assembled

NASA & HASSELL

Mission Context

- Mission developed in conjunction with Hassel Studios as an engineering solution Hassel's habitat design for the NASA 3D Printed Habitat Challenge Phase 3.
- The NASA Challenge calls for a 3D printed habitat design for deep space exploration.

Key Values

Mass to LEO: 2647 T

Mass to Martian Surface: 226 T

Mission Cost: $200-800 Billion

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Mars ISRU Habitat

Project Athena - Interplanetary Phase

Cargo Mars Transfer Vehicle

Propulsion System

- Nuclear thermal propulsion
- Hydrogen propellant

Power and Communication

- Gallium arsenide solar cells and lithium ion batteries
- TT&C antennas
  Text antenna (human MTV)
  Video antenna (human MTV)

MTV Characteristics

- Cargo MTV Mass, 1st & 2nd trip - 774T & 409 T
- Human MTV Mass - 838 T
- Total human MTV transit time - 510 days
- Number of launches to assemble cargo MTV - 13
- Number of launches to assemble human MTV - 16

Cargo MTV Dimensions

Landers & Cargo

- Vertical lander with aeroshell configuration
- Maximum lander payload capacity: 57.6 T
- 2 Landers per MTV

Fuel Modules

- 10 Aluminum tanks
- Carbon fiber beams

Launch Vehicle

SLS block 2

- Maximum payload to LEO: 108.3 t
- Maximum volume to LEO: 1320 m^3
- Estimated cost per launch: $1-3 Billion
- Could be replaced by future reusable super heavy launchers

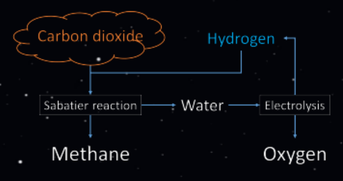
Mars Ascent Vehicle and fuel production

Mars Ascent Vehicle

- Capacity: 6 astronauts and 250 kg of payload from the surface to the MTV
- Dry mass of 12 t and uses 30.8 t of methane and liquid oxygen as propellant

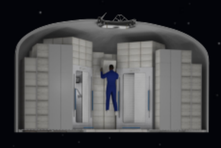
Fuel Plant

- Sabatier Electrolysis process during 5 years
- Use the carbon dioxide of the Martian atmosphere and 9 t of hydrogen brought from Earth
- Maximum power consumption 5400 W



Shielding Solution for Human MTV

- 3 cm polyethylene MTV shielding
- Additional 25 cm around the sleeping quarters



- Total mission dosage: 736 mSv / 1164 mSv (abort scenario)
- Dosage from large SPE: 59 mSv

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Project Athena - In-Situ Construction

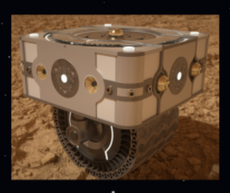
Operations on Mars

Post Landing Operations

- Rovers first find a suitable dig site
- Tasked with deploying support infrastructure, including power systems and rover support infrastructure

Build Phase

- Rovers construct the shield using additive manufacturing techniques.
- Regolith is used to fill up the central cavity, to act as a supporting structure during the build process.



Modular Robotics

- Fully modular rovers
- Consists of several separate modules that can be reconfigured to fulfill a different purpose

In-Situ Construction Phase: Key Values

- Total time taken to build the shield: 1463 days/4 years
- Total mass of rovers required: 14.7 T
- Total number of modules required: 334
- Power required for normal operations: 26 kW

Regolith Shield

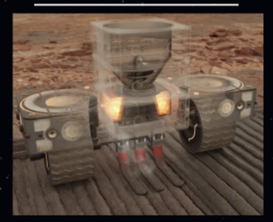
Additively manufactured regolith shield

- Protects the habitats from harmful radiation
- Built using regolith found in-situ to minimise mass taken to Mars
- Thickness of 3 m to provide adequate protection

Rover Support Infrastructure

- Acts as a garage for the rovers, where they can be reconfigured
- Also acts as their central control hub
- Uses a semi centralised control structure, where the RSI gives commands to master rovers, which give commands to slave rovers

Regolith Sintering



Preparation Process

The regolith used for sintering has a specific composition, and is obtained by filtering regolith using purpose-built refiner modules.

Sintering

Once collected from the refiner modules, the sintering rovers build the shield by layering regolith incrementally, constructing the shield from the ground up.

Key Values

Regolith Preparation time: 3 hours

Regolith Preparation temperature: 200°C

Power required: 300 W per refiner module

Key Rover Configurations

Excavator Rover

Mass: 200 kg

Carrying Capacity: 80 kg of regolith

Movement Speed: 25 cm s^{-1}

Number: 15

Sintering Rover

Mass: 100 kg

Carrying Capacity: 20 kg of regolith

Build rate: 12.5 x 10^{-5} m^3 s^{-1}

Movement Speed: 20 cm s^{-1}

Number: 23

Scout Rover

Mass: 40 kg

Movement Speed: 25 cm s^{-1}

Number: 5

Additional Modules

In addition to these, several modules will be taken to Mars to take advantage of the rovers' modularity. These modules can fulfill the needs that might otherwise require specialised rovers, and allow for great versatility during operations on Mars. These include water extraction, long-range communication and science modules, to name a few.

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Project Athena - Mars Habitat & Support

Internal Habitat

Single Module

Mass: 86.92 T

Volume: 27 m^3

Maximum diameter: 9 m

Height: 3.6 m

Full Habitat

Shape: Circular for redundancy

Design: HASSELL

Total mass: 104 T

Power needed: 17.4 kW

Temporary Habitat

Aim: Help astronauts to recover after the landing (3-4 weeks)

Habitat module: Use the lander

Life Support System

Life Support System

Food Mass: 10 T

Supplies Mass: 8 T for healthcare, hygiene, clothing and maintenance

ECLSS Volume: 12m^3 per hexagon (including redundancies)

Power: 17.4 kW

Surface Support: Power & Communications

Support Power Systems

- 5 Kilopower Fission Reactors as primary power source: provide 50 kW
- 2 Modular Photovoltaic Arrays as additional power source: provide 10 kW

Earth Communications

- Use of areostationary satellites orbiting around Mars prior to the mission
- X band antenna on the Martian surface
- Data rate of 1 Mbps

Mars Environment

Landing Site

East Hellas Crater (94E, -35.3S)

Water availability: High probability of large amount of water ice

Terrain: Flat region with sparse cobbled size or smaller rocks, loose regolith

Temperatures: -110 to 32 °C

Mean pressure: 176 Pa

Solar flux: 200 to 600 Wm^2

Science objectives: Search for life, study of the atmosphere, study of the geology

Radiation

Total mission dosage : 736 mSv

Large SEP event dosage: 1.2 mSv

Habitat shielding: 3 m Regolith shell

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