

Mars Base Requirements

Project Mars I.

ELTE Req.Eng group No.4.

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Introduction

The goal of this project is to design and implement a Mars base which fulfills the following criteria:

- The base shall serve 6 people for the entire duration of the Martian missions
- The base shall have an operational lifetime of 10 years in Martian conditions
- The base shall allow the astronauts to enter and exit the Mars rover, or make direct spacewalks
- The base shall provide organized storage for the collected geological samples. It should also provide ways of transporting these samples and allow experimentation with them.
- The base shall be able to communicate with the Mars rovers, the Mars-orbiting relay satellites, and with the space station.
- There shall be risk analysis applied, and redundancy shall be used for the necessary subsystems.
- A supply storage shall be joined to the base, which shall hold critical replacement parts for the Mars base and the Mars rover.

Goals

The success of this project is conditional on safe operation.

The customer's expectation is that the Mars base shall use the smallest possible budget, which includes design, testing, materials and cost of assembly. The ultimate goal is to design a base that is operational for at least 10 years under Martian conditions. It was agreed upon, during the discussions that reuse of the Mars base after those 10 years is not required.

Fundamental aspects are safe operation and serving a maximum of 6 people for the entire duration of the Mars mission. According to this it is necessary to use redundancy for critical components in case of failures.

The entire duration of this project is 13 years. By May 10th, 2035 the Mars base should be finished on the surface of Mars. Because of the scale and complexity inherent in this project, its design and implementation is organized into multiple milestones. According to discussions, the following milestones were chosen:

Milestone name	Milestone deadline
Design Plan	May 10th, 2025
Prototype 1	May 10th, 2028
Prototype 2	May 10th, 2030
Earth Test	May 10th, 2031
Base is on Mars	May 10th, 2035

Glossary

- Astronaut - Member of the at most 6 people mission group
- Time spent (years, months, weeks, days) are according to Earth's calendar.
- Base/Mars base - The end result of the project. The edifice that will be placed on Mars, in which people will live during the Martian missions.
- Blocks - Rooms or other larger components of the Mars base.
- ISS - International Space Station
- Mars – The fourth planet from the Sun, the second smallest planet in our Solar System
- Martian conditions- Natural conditions found on Mars, such as atmosphere, gravity, chemical composition, etc, In other words, the totality of all factors that can affect the base and all its units and users on the planet Mars, including:
 - Average temperature of -63 °C, and the possible fluctuations between -140 °C and +21 °C, cosmic rays hitting the base.¹
 - Atmospheric makeup: Carbon dioxide 95.7%, Nitrogen 2.7%, Argon 1.6%, Oxygen 0.13%
 - Average density 3.933 g/cm³
 - Surface gravity 3,71 m/s²
 - Surface gravity at the equator 3,7 m/s²
 - Escape velocity 5,027 km/s
 - Sidereal rotation time 1,025957 days(24,622962 hours)
 - Rotational speed 868,22 km/h
 - Surface pressure 0,7–0,9 kPa
- Mars rover - End product of the Mars rover project, a vehicle used to get around on Mars.
- Entire duration of martian missions- 1 year
- Spacewalk– Walk on the surface of Mars.

Interested Parties

- NASA
- Team of the Mars rover
- Team of the Supply spaceship

¹ <https://www.weather.gov/fsd/mars>

Requirements

Requirements numbering and structure

Every requirement is defined the same way, using a unique identifier and a textual description of the requirement. We use the following format to uniquely identify every requirement:

- **A_ID**, where A is the requirement area, and ID is the unique identifier of the requirement within the area.

Identifiers used for the different requirement areas:

- **M** - Requirements related to milestones
- **B** - System requirements
- **P** - Product requirements
- **A** - Astronauts
- **R** - Requirements of the Mars rover team
- **U** - Requirements of the Supply spaceship team
- **S** - Security

Design and implementation milestones

- **Prerequisites:** The prerequisite for starting each stage is the full implementation of the previous milestone.
- **Design Plan:** In this milestone the detailed design of the Mars base is being done. Duration: 3 years
- **Prototype 1:** Basic functionalities are completed in this milestone. Duration: 3 years.
- **Prototype 2:** In this milestone the Mars base specifications are narrowed down, failures are fixed. Duration: 2 years.
- **Earth Test:** In this milestone we are testing the completed Mars base on Earth, and we fix previously unnoticed failures. Duration: 1 year.
- **Transport to Mars:** In this milestone we transport the base to Mars. Duration: 4 years.

Identifier	Description
M_01	Within the Design plan the following should be completed: <ul style="list-style-type: none"> • Detailed plans of the Mars base, including visual design • Construction schedule • Maintenance manual • User manual of the Mars base
M_02	The construction schedule, maintenance guide and user guide shall be adapted to the changes made during each milestone and supplemented with new developments.

M_03	<p>By the end of the Prototype 1 milestone, the Mars base should fulfill the following criteria:</p> <ul style="list-style-type: none"> • At this stage, the Mars base does not have to meet the minimum operational lifespan requirement • All components of the Mars base shall meet the specified volumes and weights within 30% deviation limits, the components shall also be functional. • Docking with the Mars rover works. • The Mars base can communicate with the Mars rover and the Supply spaceship.
M_04	<p>By the end of the Prototype 2 milestone, the Mars base should fulfill the following criteria:</p> <ul style="list-style-type: none"> • At this stage, the Mars base shall meet the specifications for volumes and weights. • All components of the Mars base shall meet the specified volumes and weights within 0.1% deviation limits, the components shall also be functional. • The requirements for the base are met almost entirely, but smaller errors may still occur at this stage.
M_05	<p>By the end of the Earth test milestone, the Mars base shall meet all specifications, it shall be tested on planet Earth and it shall be ready for shipping and deployment.</p>
M_06	<p>By the end of the Base is on Mars milestone, the Mars base should be deployed to Mars.</p>

System requirements

Identifier	Description
B_01	The Mars base shall be manufactured from materials that can resist all Martian conditions.
B_02	The Mars base shall be able to connect to the Mars rover physically, so the procedure of getting on and off is possible without the need for astronauts to experience Martian conditions.
B_03	The astronauts can carry a package the size of a cabin baggage (50 kg/person). There is no need to store these in a different room. Storage cabinets shall be provided.
B_04	The Mars base shall have two storage systems: a scientific depository , and a repository able to store supplies, spare parts and rations .

B_05	The base does not need to be recyclable. The minimum lifespan of the base is 10 years, providing proper maintenance.
B_06	The Mars base shall require a scientific laboratory , where research experiments are done.
B_07	Human manpower can be used for the construction of the Mars base, but it should be minimized.
B_08	By the arrival of the first astronauts, the Mars base shall be completed. Installation activities of the base can be done by astronauts..
B_09	The Mars base shall be deployed to an area, where the slope of the terrain is less than 2%. The remaining inequalities shall be circumvented using adjustable legs.
B_10	The base shall be transported to Mars during 10 rounds, using a deployment tool with the capacity of: <ul style="list-style-type: none"> • weight: 20 tonnes, • size: 8 m diameter, 15 m long cylinder.
B_11	The Mars base shall be able to communicate with the Supply spaceship and the Mars rover using a 300 km range, 5 second delay radio signal. Communication with robots from the older Mars projects is not required.
B_12	The Mars base shall be able to communicate with ISS and NASA Earth bases, using radio playbacks. The delay in the communication shall be in the 4 to 24 minute interval. ²
B_13	For the energy supply of the base, the construction of the following systems are required: <ul style="list-style-type: none"> • solar panels, • thermonuclear power plants, • spare accumulators.
B_14	The following blocks require water: <ul style="list-style-type: none"> • kitchen, • hygienic block, • laboratory, • crop growing block.

² <https://www.nasa.gov/feature/goddard/2020/space-communications-7-things-you-need-to-know>

	<p>The functioning of the Mars rover does not require water, however the water which is a byproduct, can be recycled and moved back into the common water distributor.</p> <p>Storing of water is limited, therefore restriction of water usage shall be required.</p>
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Requirement of products

The structure of the base will follow a star topology. The different blocks shall be placed accordingly:

- At the center of the topology shall be a **community area**, which the other rooms will open from.
- The two locks (the **bridge connecting to the Mars rover** and the **entrance lock**) shall be placed adversely.
- The storage rooms (the **scientific depository**, and the repository able to store **supplies, spare parts and rations**) shall be next to each other, adversely to the **living blocks**.
- The living blocks (**sleeping capsules**) shall be next to the hygienic blocks.
- The storage blocks shall be next to the bridge connecting to the Mars rover, therefore importing supplies from the Mars rover will be easy.
- The Mars base shall include a **crop growing block**.
- A **connection point** shall be left free. This opens up the possibility to **connect to another Mars base using the star topology** in the future.

Identifier	Description
P_01	<p>The community place shall maintain a temperature between 18-25 °C. It shall be able to be separated to a smaller and a larger area, where two teams can have two independent discussions simultaneously. The ratio between the two areas shall be 1:2. The community place shall have the following components:</p> <ul style="list-style-type: none"> • The bigger room shall contain a kitchen. • The smaller room shall contain a gym, which can be opened from the ceiling.
P_02	<p>The kitchen shall maintain a temperature between 18-25°C. It shall also have water on tap. The kitchen shall have the following functionalities:</p> <ul style="list-style-type: none"> • Ability to water up food. • Ability to wash the dishes. • Ability to heat up food. • Ability to make food. (This requires additional functionalities, such as an oven.)
P_03	<p>The gym shall maintain a temperature between 18-25°C. The astronauts shall be able to keep themselves in shape, so the block shall have cardio machines (e.g.: treadmill, stationary bicycle).</p>

P_04	<p>The hygienic blocks shall maintain a temperature between 18-25 °C. They also require water on the tap. Two hygienic blocks shall contain the following:</p> <ul style="list-style-type: none"> • A combined shower-bathroom unit (1 shower, 1 toilet is sufficient), • A bathroom only unit. (1 toilet is sufficient). <p>The blocks shall be accessible from both the living- and the community blocks.</p>
P_05	<p>The living blocks shall maintain a temperature between 18-25 °C. The living block shall contain the following components:</p> <ul style="list-style-type: none"> • 6 sleeping capsules <ul style="list-style-type: none"> ◦ All capsules have sizes 1x1x2.5 m • Lockers, the astronauts can bring a cabin sized package (50 kg / person), the ability to store this shall be provided. • The hygienic blocks shall be next to the living blocks.
P_06	<p>The laboratory shall maintain a temperature between 18-25 °C. It also requires water on the tap. The laboratory shall provide space for the following activities:</p> <ul style="list-style-type: none"> • rock analysis, • analysis of chemical reactions, • cutting roc samples into 20 cm³ sized cubes, • labeling, • physical formatting, e.g.: drilling, cutting.
P_07	<p>The scientific depository shall have a near Martian temperature, but with a minimum of 5 °C. This block shall be separated from the supply repository. The scientific depository shall provide 10 m³ storage space.</p> <ul style="list-style-type: none"> • It shall be located near the bridge connecting to the Mars rover and the scientific laboratory.
P_08	<p>The supply repository shall provide ideal circumstances for food storage. It shall have the ability to store the following:</p> <ul style="list-style-type: none"> • spare parts of the Mars base, other parts required for maintenance, • supplies required to maintain the quality of life, • spare parts of the Mars rover, • food. <p>The spaceship with the supplies arrives every quarter. Unique orders can be processed in a 1.5 year period. The inventory shall be maintained accordingly.</p>
P_09	<p>The crop growing block shall be regulated between temperatures 5-25 °C. It shall have a greenhouse like environment. It also requires water.</p>
P_10	<p>Getting in and out of the Mars rover inside the Mars base shall not be feasible. The bridge shall be used instead.</p>
P_11	<p>Getting into the Supply spaceship shall not be feasible, only communication with the ship is required.</p>

P_12	To start a space walk, getting from the Mars base to Mars' surface shall be done using the spacewalk lock .
P_13	<p>The Bridge for the Mars rover is a controllable passageway that was made for vertical adjustments. Using the bridge, the Mars rover can be connected to the base, therefore the astronauts can move between the two.</p> <p>The bridge shall also be capable of fueling the Mars rover. This includes charging the accumulators, and supplying water.</p> <p>It shall also be used for space walks.</p>
P_14	<p>The fueling of the Mars rover shall be done using the base's energy and water supplies. This shall be done parallel to the connection with the bridge.</p> <p>The base shall also be capable of fueling another rover in parallel independent of the bridge.</p>
P_15	<p>The simple decomposition thermonuclear power plant shall be a separate block. It shall not be connected to the Mars base directly but it shall be controlled from it. The plant shall be 20 meters from the base, with proper shading.</p> <p>The power plant shall be made up from multiple blocks. If one block malfunctions, the others shall not stop working.</p>
P_16	The separation of blocks does not require connecting corridors, one sluice gate is sufficient.

Stakeholder requirements

Mars-rover team requirements

Identifier	Description
R_01	The two Mars rovers will go 200 km max away from the Mars base.
R_02	A communication channel shall be required between the rovers and the base. The communication shall be possible with either one or both rovers at the same time. When

	a rover leaves the 200km area of the base, communication shall still be possible in a 300 km range.
R_03	A docking bridge is required, which evens out the vertical differences of the surface, functions as a bridge between the base and the rover, while ensuring the input and output of astronauts and load. Therefore it should connect to the vehicle properly.
R_04	Fueling of the Mars rovers shall use the power system of the Mars base. The connection to the docking bridge and the fueling of the rovers shall be done parallelly. Parallel with this, the other rover shall be fueled also.

Supply spaceship team requirements

Identifier	Description
U_01	A communication channel shall be established, where the spaceship and the base can send and receive measuring data.
U_02	The fueling of the spaceship shall not be required from the Mars base.
U_03	The spaceship arrives once every quarter with new supplies. Unique orders can be served with a 1.5 year run-through.

Risk analysis

Event	Severity (1-10)	Probability (0-100%)	Solution/alternative - if exists
All outside locks malfunction.	5	0.2%	Separating a block can substitute a malfunctioning lock, using the sluice gate between the blocks.
The thermonuclear power plant does not provide electricity.	8	1%	Additional batteries are required while the plant's repair works are going on.
Bridge malfunctions, we are unable to connect to the Mars rover.	3	0.3%	Using the space walk lock we can go to the surface of Mars, and into the rover.
The space walk lock malfunctions.	1	0.1%	We can go out to Mars' surface using the bridge for the rovers.
Crop growing block malfunctions and we are unable to grow food.	6	0.3%	We can send a unique order to the supply spaceship, and live off of the remaining supplies in the repository for the next 1.5 years.
Water storage malfunctions (e.g.: poisoning, contamination)	8	0.1%	-
Air filter malfunctions	9	0.1%	-