A Mission to the Red Planet

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The objective of this report is to present design concept of the first human mission to the planet Mars, focusing on the trajectory and launch windows, the ascent and descent for both Earth and Mars, the interplanetary transport of both cargo and humans to and from Mars, and the habitat and research. The mission will consist of two parts; a cargo transport consisting of two interplanetary vehicles and a manned vehicle with six people, going to Mars, and one manned vehicle returning to Earth. The launches of the cargo and the crewed interplanetary vehicles will take place in 2031 and 2033 respectively. The duration of the two different transfers will be 320 respectively 178 days. The launches from the surface of Earth will be done by Falcon Heavy rockets and the landing on Mars by a lander consisting of the commercial DragonRider capsule. This capsule will later also be used for reentry and landing on Earth. The interplanetary vehicle will have Water Walls (and other life support systems) in order to protect the crew and keep them safe. On Mars, different research topics will be investigated; water on Mars, harvesting plants and Mars geology. During the duration on Mars, the crew will live in the commercial habitat Bigelow 330 manufactured by Bigelow Aerospace.

Nomenclature

ISS	=	International Space Station
LEO	=	Low Earth Orbit
LMO	=	Low Mars Orbit
MAV	=	Mars Ascent Vehicle
TOF	=	Time of Flight

1. Introduction

Why go to Mars? Why put humans on Mars? The questions rising when presenting a manned mission to the planet Mars are fundamental. But so is the human drive to travel high above the Earth's surface into space. The fascination for what is out there has motivated and spurred humans to go to space throughout the history. The first manned spaceflight took place in 1961, and Yuri Gagarin was the first man in space [1]. Today, there are several manned missions carried out each year, for instance the crew changing flights to the ISS [1].

Mars is the most accessible planet in the solar system after Earth itself, so a manned mission to Mars may be seen as a part of human evolution [2]. It can give insight in the planetology of Mars and drive both scientific and technological development; it can bring countries together in global space programs, and it can be an inspiration to people all around the world.

Since the mid nineties, several studies have provided input on how to design and conduct a manned mission to Mars [2]. However, human exploration of Mars will nonetheless be a complex task, since there are still many new factors to be handled. There are major differences between manned and unmanned missions to space, such as basic design and management, and funding [1], and a longer manned mission - such as a manned mission to Mars - also creates new difficulties.

The first manned mission to Mars is part of a broader program, and is the first step towards a possible colonization of Mars with permanent habitats. The main objective (of this first mission) is to build a research base on the surface of the planet. The mission will transport humans to the surface of Mars and bring them all back to Earth.

The goal of this project is to organize and manage the overall mission coordination of the first manned mission to Mars, and to present a concept for the overall design of the mission.

2. Methods

2.1. Project setup

A manned mission to space starts with defining a broad objective and its corresponding constraints, then progresses to a conceptual design of the systems required as well as all associated elements that will meet the objectives in an efficient way [1]. For the purposes of this project, the Mars Mission is divided into one overall mission coordination group and three other groups; Ascent and Descent, Interplanetary Transfer and Life on Mars. (Each area has a group responsible for the detailed work on issues regarding that specific area.)

In the overall mission coordination group, the goal is to coordinate the whole mission and confirm that the work done by the groups is consistent and coherent. The group is also a channel for communication between the groups to execute the work efficiently. Together with the formerly mentioned, this group also handles technical areas of interest for the overall mission that is not dealt with by any of the other groups. The challenge is to design according to requirements, since the project also includes setting up requirements for the overall mission itself.

Each group specializes within their field; however, several groups need to communicate (for instance) over mass budget, crew composition and other aspects that affect the overall mission.

The work of the groups includes:

- *Ascent and Descent*: investigating the launches and landings of all vehicles of the mission, as well as the launch and landing vehicles themselves (and other related items).
- *Interplanetary Transfer*: designing and planning the function of the interplanetary vehicles, both manned and unmanned, including propulsion systems for the interplanetary spaceflight.
- *Life on Mars*: investigating and deciding what type of research will be conducted and how the crew will live on Mars.

2.2. Assumptions

For the purposes of this project the following assumptions have been made as a foundation for the mission:

- An unmanned precursor mission to deploy a functional navigation system on the surface of Mars has been carried out. It has successfully set up a navigation system on the surface of Mars with enough accuracy to navigate and land the vehicles within meter of each other. This type of mission can be assumed to succeed within the given timeframe until the start of the manned mission, since technology of this kind already exists.
- The funding for the mission is assumed to be enough to cover the expected cost of the mission [3] The cost itself will be estimated (roughly) in section 4.8.
- The mission, and the possibility to carry it out is assumed not to be affected by any political, economical issues or natural disasters.
- The technology needed is available.

3. Mission Planning

To carry out the overall mission, several steps must be taken in order for the subgroups to gain material to work with. Firstly, the broad mission objectives must be decided upon, which is presented in section 3.1. After that the mission requirements and constraints can be found, and the next step is to develop alternatives for mission concepts and architectures, after which system drivers and critical requirements for the concepts are to be identified. This is presented in section 4 with subsections. From that, a baseline mission concept and architecture is presented in the Conclusions section. For the purpose of this project, the work does not stretch further than this, but to conclude the work, steps 6 through 8 are also carried out in general (see table 1).

Table 1: *Mission design steps for manned missions [1]*

Step	Description
1.	Define broad mission objectives
2.	Define mission requirements and constraints
3.	Develop alternatives for mission concepts and architectures
4.	Identify system drivers and critical requirements for the concepts from Step 3.
5.	Select mission baseline concept and architecture
6.	Define system or subsystem requirements
7.	Document and choices and rationale
8.	Iterate and integrate the design (going from Step 1. again)

3.1. Mission Objectives

The overall mission objective is to send humans to Mars and bring them back again. In specific terms, this mission will be part of a broader program with several mission and the goal to build a colony on Mars. This mission is the first mission to Mars and will apart from exploration and conducting research also prepare for subsequent mission.

4. Mission Summary

4.1. Trajectories and Launch WIndows

In terms of mission planning, the cycle of mission opportunities repeats every 15 years with windows every 2.1 years [4]. However, it is extremely important to set a feasible but challenging deadline for the mission, otherwise there will be no demand to develop the necessary technology and build the necessary equipment. Said that, this mission is designed to have it first launch in 2031.

The effects of space travel on human body will be discussed in section 4.4.1, but it is sensible to conclude beforehand that the longer in space, more harmful is to the human body. Therefore, the trajectory used to transport humans to mars must balance the interplanetary trip time with cost. Besides the type of trajectory, the cost (i.e. propellant) is also influenced by the date that the launch occur and, consequently, the choice of launch window is likewise important to the mission design. Nevertheless, the energy efficient trajectories have the drawback of long duration flight and on the other hand, short duration flight require more propellant. [5]

This project will have a precursor mission to deliver the equipment necessary for the life on mars in advance. The cargo mission will follow the minimum energy trajectory while the crew will be transported by a short duration flight trajectory in a lighter module with only the necessary to maintain life during transit in space. With that in mind, the analysis by [6] provide the flight opportunities and its correspondent energy. Matching the requirements of this project and the launch opportunities, this mission has the following dates:

Table 2: *Mission Dates Summary*

Earth - Mars	
Cargo	
Departure	2031-02-22
TOF	320 days
Arrival	2032-01-08

Crew	
Departure	2033-04-04
TOF	178 days
Arrival	2033-09-29

Mars - Earth	
Crew	
Departure	2035-05-08
TOF	198 days
Arrival	2035-11-22
Time on Mars	586 days
Total Duration	962 days

Although not on the scope of this project, it is part of a mars mission design to prepare a re-supply emergency mission. In order to increase the launch opportunities, a Venus flyby trajectory is studied in [6]. Even though this trajectory is more expensive in terms of propellant, provides strategic advantages if any off-nominal case forces a re-supply mission to be sent to mars.

4.2. Crew Selection

The number of people are chosen based on the tasks required of the crew, considerations in terms of safety and risks, as well as the dynamics of a crew with international background. The crew must rely on experts able to carry the whole mission and proceed with the experiments on Mars, so were chosen: a comander, a flight engineer, a eletronic engineer, an exo-biologist, a geologist and a psychologist. Among them, is required someone with basic skills in medicine.

4.3. Ascent and Descent

In order to send something to Mars it first has to ascent from the surface of the Earth. The plan for this mission is to assemble the cargo vehicles and the crew vehicle in Low Earth Orbit (LEO) and from there send them on a trajectory towards Mars. Since this mission is planned to happen within 17 years from now, some existing space launch system or a promising space launch system is needed.

Best suited would be the two staged Falcon Heavy, being designed and manufactured by SpaceX and will have its first test flight in 2014. Falcon Heavy will be able to lift a payload of 53 000 kg to LEO [7]. One purpose of using the Falcon Heavy is that the Mars habitat will have a mass of approximately 45 000 kg giving a requirement on the space launch system needing to be able to lift at least 45 000 kg to LEO.

The plan for this mission is to send the cargo to Mars before the crew so that as much as possible is already set up on Mars when the crew arrives. The Mars lander will be sent with the cargo and put in orbit around Mars. After the crew have arrived to Low Mars Orbit (LMO) they will use the Mars lander to land on the surface of Mars. The Mars lander will also be used as the Mars Ascent Vehicle (MAV). The top part of the Mars lander will consist of the commercial DragonRider spacecraft capsule, also designed and manufactured by SpaceX, which later in the mission will be used to re-enter Earth's atmosphere and eventually land on Earth. The DragonRider is a rewed version of SpaceX's Dragon capsule which has the benefit of having an integrated launch abort system.

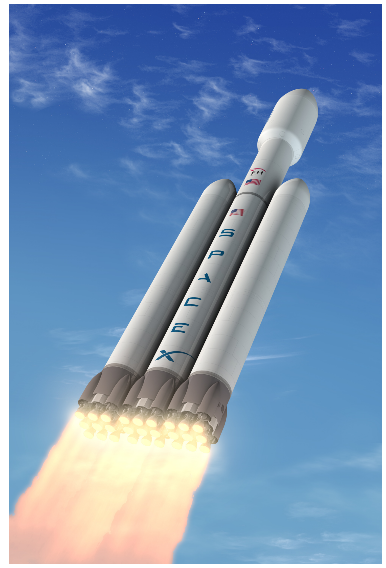

Figure 1: *Falcon Heavy [7]*

However, in order to be able to perform a safe landing, the Mars lander will, in its first stage use aerobraking and heat shields to slow down its speed. The lander will then use parachutes to decrease the speed even more and for the last stage thrusters will be used. As mentioned earlier, the Mars lander will also be used as the Mars Ascent Vehicle which means that it will need enough fuel to also get up to LMO again. This fuel will not be transported to Mars from Earth but rather produced on the surface of Mars. The Martian atmosphere is extremely thin and composed mostly of carbon dioxide. This carbon dioxide can be used to produce methane according to formula 1.

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O \tag{1}$$

The water can then be electrolyzed to produce oxygen and hydrogen; this hydrogen can again be used to produce more methane. The production of fuel will start already before the crew arrives to Mars, which makes the landing precision critical. In order to be able to land in a close and precise proximity to the fuel producing station the Mars lander will need some sort of maneuverable ability during landing.

In order to be able to land in a close proximity to the fuel station and the habitat some kind of navigation system need to be set up beforehand. Therefore a smaller vehicle will be sent beforehand to set up beacons in order to be able to land the habitat, fuel station and the Mars lander at the same location. For this at least four beacons is needed.

After ascending to LMO the MAV will dock with the interplanetary vehicle for a return trip back to Earth. The entire Mars lander/MAV except from the DragonRider capsule will be left in LMO for future Mars missions. The DragonRider capsule will then go back to Earth with the interplanetary vehicle and be used for reentry to Earth. To save energy only the DragonRider capsule will return to the surface of Earth.

4.4. Interplanetary Transfer

The fundamental driving requirements for the interplanetary transfer are life support, environmental control and free habitable volume [8]. From these requirements, the radiation shielding, life support systems and other areas/issues can be derived, and they can be traced both to the journey between planets and the surface stay on Mars.

4.4.1. Psychology and Health during transport

The human body is affected in many ways when staying in space. Some effects come from being in a state of weightlessness, and from both short-term and long-term radiation exposure, others have psychological causes and depend on human interaction. The list below shows some issues that (may) affect astronauts of human spaceflight [9].

- Conflicts
- Microbiology
- Isolation
- Weightlessness
- Emergencies
- Nutrition
- Radiation
- Psychic Load

Examples of how the body is affected by weightlessness are loss of bone mass and muscle mass, and disturbance of balance that may lead to problems with movement and assessing distances [9]. Radiation exposure, specifically from Solar Particle Events (SPE) can lead to acute radiation sickness, whereas long-term effects such as cancer and normal tissue complications come from Galactic Cosmic Rays (GCR) [9]. In a long-term mission (such as a manned mission to Mars), issues like maintaining motivation and individual well being arise. Working in a small group, such as a crew of six, may also pose difficulties due to the risk for group thinking and crisis handling situations.

4.4.2. Crew Module

The crew module used in this mission is a module of the type BA 330 by Bigelow Aerospace. It can host a crew of six astronauts and has a volume of 330 m^3 [10]. It provides radiation protection and ballistic protection, and out of the two propulsion systems used, one can be refueled and reused [10]

4.4.3. Radiation Shielding

To shield off excess radiation that exists in space and to which the crew is subjected during the interplanetary flight, there are many different systems that can be used. Active types of radiation shielding that may be used are e.g. superconducting shields and electrostatic active shields.

Another example is the so-called Water Wall, which is currently under development from NASA and will be used for the investigated mission to Mars. As the name suggests, the Water Wall is a wall filled with water. It is a passive and redundant biological and chemical concept, which is analogous to nature's own approach (here on Earth), and it uses forward osmosis in a specifically designed bag. Figure [**?**] shows the modular concept of Water Walls. Apart from providing shielding from radiation, this device also integrates life support systems and thermal as well as structural functions, and at the same time it saves mass [11].

4.4.4. Life Support Systems

The health and safety of the crew is vital to any manned mission, especially for a long-term mission such as the one considered in this mission. Life support systems is/are a fundamental driver and requirements coupled to it/them are (of course) highly prioritized. The life support system must provide a crew of six with oxygen, water and reasonable temperature, and it should be able to handle waste products that the crew produces during the mission. It is also important to have fire detection and suppression as well as radiation protection. Furthermore, it is also essential to continuously control the quality of the living environment that the transplanetary vehicle constitutes.

Air revitalization can be done with the Water Walls as seen in Figure 2. The algae absorb CO_2 from the air and stores carbon whilst releasing oxygen that can be used by the crew [11]. Furthermore, the algae are edible. Waste handling and water recycling is also done by the Water Walls, in blocks called Urine and Greywater Processing and Blackwater and Solid Waste Processing (see Figure X11 [?]

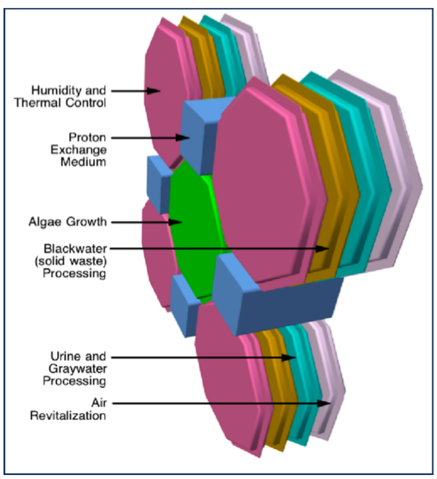

Figure 2: *Modular Water Walls concept from NASA [11])*

4.4.5. Artificial Gravity

During the long-term interplanetary transport, the effects from the weightless environment on the astronauts can be counteracted (to some extent) in several ways; one way is to recreate the gravity field of Earth. There are several ways to create this sort of artificial gravity on board the vehicle and the most relevant for the investigated mission are [12]:

- *Linear acceleration*: The vehicle will accelerate until it reaches 1g or even more. However, this requires fuel and the engine must have high specific impulse. The advantage is that the transit time in space will decrease.
- *Rotation*: By spinning the vehicle, artificial gravity can be created. This solution poses problems such as the required dimensions of the vehicle and possible sickness symptoms among the astronauts. In general, the artificial gravity created reaches 10% of Earth's gravity, since higher values are not recommended. The major advantage of this system is that no extra mass is needed.

4.4.6. Power system

The technologies for a power system considered for this type of mission are dependent on two areas: the assumption about what technology can be used in 2033 and the duration of the flight. The trajectories chosen for the mission (see section [**?**]) require high thrust and high impulse propulsion systems. For these types of systems, the traditional chemical propulsion is not efficient, since it will present several problems; the amount of launches needed to reach LEO is one problem ([**?**]). Issues with storing the propellant needed during the flight is another. The option considered for the vehicle is instead nuclear thermal propulsion, NTP.

With an NTP system, fewer launches are needed [5]. The system has a high thrust and a high specific impulse, $I_{sp} = 875 - 950s$ [5]. NTP can be used for both the crew vehicle and the cargo vehicle. The technology has been demonstrated to have a high level of readiness and has been ground-tested with several types of fuel forms [5].

4.4.7. Onboard the Interplanetary Vehicle

A type of countermeasure to cope with the effects of the (close to) weightless environment on board the interplanetary vehicle is physical training. Training exercises provide strength and endurance training, which (to some extent) prevents the loss of muscle mass and maintains physical performance in terms of cardiovascular capacity, and balance and coordination [9]. Physical training should be conducted every day to withhold good physical health. A training program is usually between two and three hours [9].

Apart from training, and some onboard research and scientific activities such as solar science measurements, another important undertaking for the humans on board the transplanetary vehicle is maintenance work. During the first mission to Mars, operating the vehicle and performing maintenance work will likely take a substantial amount of time, although this work during interplanetary transport may not be as large in other phases of the mission [2]. To facilitate the operations and maintenance of the different systems, they can be designed as modular and easily repaired [2].

4.5. Landing Site

Every colonization has a starting point. In humanity history, though some settlement places have been chosen by accident, most were due to the optimum conditions for the activities meant. Envisioning the whole mission, one can see the that some steps are very dependent on landing site and colonization.

Since the mission three main goals are 1) going from Earth to Mars, 2) making possible the human life in Mars 2) doing research on the planet, the mission must select a place able to provide a convergence of three main requisites. Otherwise, the mission can be totally condemned [13].

4.5.1. Plains

Mars surface can be very rugged. For example, while the highest peak on Earth is the Mount Everest with 8,848 m, the Olympus Mons situated on Mars is more than 26,000 m high. Since Mars gravity is low and the whole planet magma solidified much earlier and faster than Earths, the surface did not get enough time to spread around equally [14].

Since it would be impossible to carry all the human facilities in a single vehicle, the mission intends to connect some modules. The idea is to land them using the same system which is currently in development by SpaceX Grasshopper to perform precise landings with support of orientation system. However, they cannot be landed too close to each other because the a installed module may be damaged by the exhausting gases from a module being landed.

So the modules will feature a locomotion system to make viable a safe attachment. This is the reason that it's essentially important to find a flatter area where the vehicles can be attached together without further difficulties.

4.5.2. Temperature

The only place where humans are already sure there is water is the the polar caps, what could be very useful and viable for the crew. However, the extremely low temperatures derails this possibility, making the choice for an warmer area almost an obligation.

Due to not having a well formed atmosphere, the temperature varies much more than Earth: the lows can reach about $-143°C$, during the winter at polar caps and the highs may get up to $35°C$, in equatorial area, during the summer.

4.5.3. Scientific Activities

As mentioned before, having humans on Mars opens up a large range of scientific activities that cannot be done by rovers and satellites. Also, In this point, Mars offers a plenty of topics, but there are places that are better than others. For example, one of the biggest challenges is to understand the presence (current or past) of water in Mars. And while some points features geological formations that could explain it, some do not.

So, to do science it is really important to have a viable place where actually there is matter of science.

4.5.4. Landing Area

The team analyzed some phy maps provided by Space Agencies such as NASA and ESA.

The first task was mostly search for "constant colored areas", where the topography is flatter and the vehicles could land easier. Some promising were further investigated on maps which could appoint the places' names.

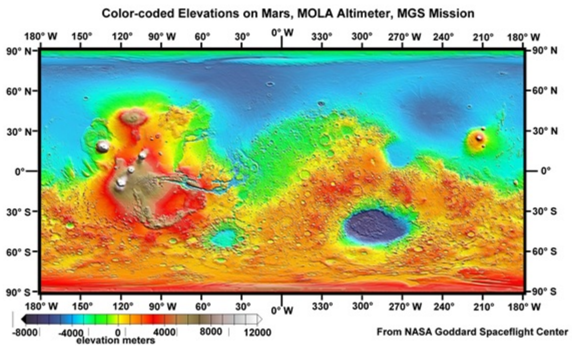

Figure 3: *Topography of Mars surface showing color-coded elevations [15]*

This first process was not too much effective, since flatter surfaces can be found in several areas, with different levels.

So the next step was to use topographic maps, also provided by Space Agencies as the following picture shows. As one can see, warmer areas are located all along the equator. In this picture, the warmer areas are displayed on the south of the equator because and as it happens on Earth, the planet features seasons as well.

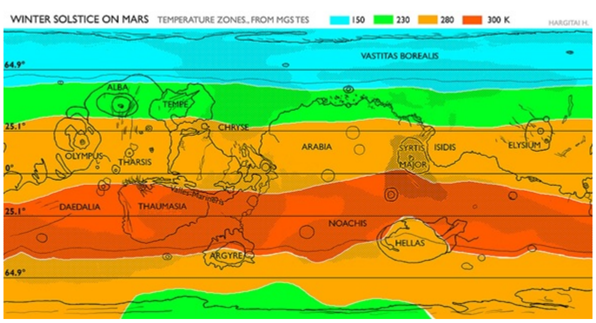

Figure 4: *Climate on Mars surface divided into temperature zones [16]*

Then, by overlapping the two maps, the areas where the two essential requisites are found could be revealed. And as done before, the most promising areas were identified and studied in technical papers about Mars geography.

The last step was to check which kind of science could be done in each of the areas. It was preferable to find places where research which could answer questions regarding the water history on Mars can be answered.

This process led to the Meridiani Planum. Some features about the area are provided in the table below.

The same place where NASA currently operates the rover Opportunity due to the great matter of science found in the place. Meridiani Planum features a rare occurrence of gray crystalline hematite, which, on Earth is often enabled by presence of liquid water. Regarding some samples collected by Opportunity, "the clearest evidence for liquid water on Mars that we have found in our eight years on the planet." [17]. Furthermore, the place host other kind of very interesting rocks and geological formations .

4.6. Research on Mars

In spite of having explored the universe for centuries, humankind still does not have the answer to an old question: “Are we alone in universe?”. Although we know an infinity number of planets in cosmos, we still were not able to find a single evidence that life as known could transcend the Earth; in past, present or future. One can be sure this mission will not discover a whole civilization on Mars (as imagined for some fiction authors many time ago), but it can provide very relevant information what concerns the capacity of planet to support life. In this topic, everything matters: from the initial events that led to the planet’s shaping, to the current conditions that enable others phenomena; everything might help to expand this knowledge and yield some very pertinent results.

Furthermore, the fact of confining a crew of 6 people for a very a long period in special environments is already a challenge itself. The crew must focus in the scientific and technical activities while maintain a cool atmosphere to work and stand the whole mission.

4.6.1. Water

It is the most essential substance for life, as we know. It is well known that Mars features frozen water on its pole caps. In addition, the planet also presents some very peculiar geological formations that indicate that water (or some other liquid) has flown through it a long time ago. However, we are still not able to explain how this water was created and how it vanished. In order to understand a little about this process, the mission will take place in an area where was found occurrence of gray crystalline hematite, which is deeply related to the presence of liquid water on Earth. This is why the crew needs a specialized geologist. And if these activities produce promising results, equipment able to drill Mars soil will be taken to the planet in next missions.

To explore further intends to carry equipment able to explore Mars surface. For this task, astronauts will carry extra-vehicular activities (EVA's), along with a rover and an Unmanned Aerial Vehicle (UAV). The UAV (which has a longer range) will provide the "big pictures" for the crew. Then, the places of interest are selected and the humans and the rover can explore further.

Finding liquid water will not only produce scientific data, but it can also serve the human crew on the planet, what will make the colonization easier for next missions.

4.6.2. Exobiology

Life needs six essential elemental ingredients: carbon, hydrogen, nitrogen, oxygen, phosphorus and sulfur. With an exception of some microbes able to substitutes arsenic atoms for phosphorus, all organisms we know need these six elements to run their metabolism. However, even if all these elements are found somewhere, some particular criteria of temperature, pressure, radiation levels, etc., must be checked. Mars is a planet which already revealed the capacity of not "creating" life as we know.

However, in order to produce more scientific material regarding Mars capacity to hold life, ground exploration will be done to identify the soil composition more precisely. In addition, an exo-biologic laboratory will be installed to run tests with organisms known for being able to stand this kind of environment, for instance, some bacteria known as Extremophiles, found on remote regions of the Earth, such as volcanoes, mountaintops and Polar Regions. In addition, research with plants with great capacity of adaptation will be carried as well.

4.7. Off-nominal case

There are several things that can go wrong during a mission to Mars and therefore it is always important to think one step ahead in order to try eliminating these factors. Some off-nominal cases have been listed below and solutions for them are discussed.

- The first thing that can go wrong is that there is something missing when it is time to launch. The launch windows for going to Mars appear once every 2.1 years in a cycle of 15 years. This means that the most efficient way to send a vehicle to Mars appears once every 15 years. It is not acceptable to wait 15 years for the next launch opportunity if something is not ready at the deadline. Therefore this mission is planned to have the opportunity to launch at the every 2.1 years launch windows. However, let us say that the mission cannot be launch at the launch window chosen for the mission but that the modules for assembling the interplanetary vehicles are already launched to LEO. Then it is important that the interplanetary vehicles can stay in LEO for an extra 2.1 years. This forces stricter requirements on the vehicles.

- In the case where the mission is needed to be aborted, and the crewed mission has already been launched, the free-return trajectory is of interest. For this to be an option, the crewed interplanetary vehicle need to have enough life support for the crew to survive in the vehicle for the extra time needed to reach Earth again. The mission planned and described in this paper will have that opportunity.

- In the case where a re-supply mission is needed to be sent to Mars, a Venus flyby trajectory is of interest. This trajectory has strategic advantages but is however more expensive in terms of propellant. This case is studied more in [6].

4.8. Cost Estimate

Giving a good estimation of the cost of a crewed mission to Mars is very difficult because a lot of the equipment and modules needed have never been produced before. However, rough estimates can be given and agencies such as NASA gave an estimate in 1997 in the order of 30 to 40 billion dollars. The really big cost of a crewed mission to Mars is taken up by the boosters, needed for the transportation vehicles. That is, to send equipment from Earth to LEO and from LEO to Mars. This cost, NASA estimates to stand for half the total cost of the mission [18]. Nevertheless, this estimate was done in 1997 which is over 15 years ago.

By using the SpaceX Falcon Heavy rocket to launch equipment to LEO the cost can be decreased. The cost of using Falcon Heavy is $\$2,200/kg$. The cost for the habitat, Bigelow 330 is in the order of U$ 100 million. Except from all of the hardware costs one also have to include the administrative costs and all that comes with it. The cost estimate of 30 to 40 billion dollars is however less than half the cost of the Apollo programme that put humans on the Moon. When it comes to the cost of a crewed mission to Mars it is just a question of priorities and wanting to make it happen. There is a lot of other things such as war that cost several times more than what a crewed mission to Mars would do.

5. Conclusions

This mission has consisted of in total four sub groups which has had the responsibility for one part of the mission each. The group of this paper has been in charge of the mission coordination. This includes everything from communication within and between the different groups as well as making overall decisions. This has not been an easy task and there is a lot of opinions and suggestions that has has been needed to be taken into account. The result and conclusion of how the mission will look like is followed below.

The Mars mission will consist of in total three interplanetary vehicles and two for cargo and one for crew. The total duration of the mission is 962 days, 586 of which are on Mars. Since the cargo is not as affected by the space environment as the crew the cargo can be sent on a slower trajectory which is more cost efficient. The crew on the other hand is more negatively affected and will therefore be sent on a faster but more costly trajectory.

The Falcon Heavy will be used to launch from Earth surface and there will be a combined Mars lander and Mars Ascent Vehicle for both cargo and crew. In order for the crew to stay alive the interplanetary vehicle need a life support system which contains everything from food and oxygen to radiation protection. One technology used onboard is the Water Walls.

The landing site has been chosen to be a location called Meridiani Planum and is chosen be- cause it is believed that water exist in that area and it is of geological interest. The research conducted on Mars will include water exploration and exobiology.

The main conclusion is that a crewed Mars mission should be possible and reachable within 17 years as far as the technology continue in the same direction as of now and that the humankind have the will and strenght to do it.

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