Mount Olympus Mons Ascension Mission Overall Coordination - Team Red

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***Abstract*—Mars exploration is the next big step that all space agencies and companies are trying to achieve. A mission to be the first crew to climb the Martian Olympus Mons is envisaged for 2038. This report, which is part of a complete study, investigates the context of such mission. First it introduces the mission profile designed by the whole team, as well as the assumptions made. Then an estimation of the cost is carried out to set the total cost to 37.49 billion USD. The main risks that the mission may face as well as the political and social context are analyzed to understand their impact on the mission. Finally, the management process is outlined.**

***Index Terms*—Mars, Mission, Olympus Mons, Tantalus.**

Nomenclature

AMCM	Advanced Mission Cost Model
CM	Crew Module
DDT&E	Design, Development, Test, Evaluation
ESA	European Space Agency
EVA	Extravehicular Activity
JSC	Johnson Space Center
LCC	Life Cycle Cost
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
RF	Refueler
SLS	Space Launch System
SP	Supply Vehicle
USD	US-Dollar

I. Introduction

Olympus Mons is the highest mountain in the Solar System, with over 624 km in diameter [1]. The volcano is over 21 km tall, more than twice the height of Mount Everest. In 2038, a multi-billionaire sets up a 100 million USD award for the first team to succeed Olympus Mons. It has been assumed that a few missions have already been carried out and that there exists a facility on Mars that produces Methane (CH_4), Oxygen (O_2) and Water (H_2O). This mission is a literal translation of Star Trek's popular quote, 'To boldly go where no being has gone before'.

The mission was named Tantalus in reference to the Greek mythological figure [2], who can also be seen in the created logo which is shown in Figure 1. Tantalus was a mortal man known for having been welcomed to the Gods' table in Olympus. There, he is said to have abused Zeus' hospitality by stealing ambrosia and nectar to bring them back to his people on Earth, in addition to revealing the secrets of the gods. For having desired to reach Olympus and to become a god himself, Tantalus was punished: standing eternally in a pool of water beneath a fruit tree, he was neither able to reach the fruits or drink the water. For all this reasons, the name Tantalus is nowadays associated with a person who yearns for something that is inaccessible to him or her. Then, what could be a better name than Tantalus for a mission which ultimate goal, rising from the status of mere terrestrial human being and climbing Olympus Mons, would be regarded as impossible by many? Completing the mission would represent Tantalus, finally managing to reach his desired target after much effort.

Fig. 1. Mission Logo

II. Mission Description

The mission's general overview was formulated after collaboration with all the groups involved in this study. As the design of those groups gained momentum, the mission description was updated. The technology is based on extrapolation of products and technologies currently available or which are expected to exist before the year 2038.

A. Mission Objectives

This conceptual study on a Mars Mission is based on the course SD2905 - Human Spaceflight at KTH Royal Institute of Technology at Stockholm, Sweden. The mission's primary objective is to win a competition and a reward of 100 million USD by successfully attempting to climb Olympus Mons, the highest mountain in the Solar System, with a crew coming from Earth, and returning to Earth without any loss of human life. Additionally, it strives to tackle the problems faced in an out-of-nominal scenario.

B. Subgroup Objectives

The management of the Tantalus mission was divided into Overall Coordination, Mission Design, Human Aspects, Mars Operations and Space Vehicles.

1) Overall Coordination: The Overall Coordination group was entrusted with the task of providing the platform necessary for communication and data exchange between the different subgroups, and making sure all subgroups used the same set of data for their analyses.

2) Mission Design: The Mission Design group [3] was tasked with addressing the Time Estimates, Trajectory, Capture Speed (Mars and Earth), Delta-V estimate, Risk Analysis, and Space Vehicle Requirements.

3) Human Aspects: The Human Aspects group [4] was assigned the task of working on the onboard vital (Air, water, food, safety) and on-vital systems (Physical and Mental training, Hygiene) aiding humans. Additionally, they aided in the crew selection.

4) Mars Operations: The Mars Operations group [5] was responsible for addressing the technical aspects of the space-suit, duration of the Itinerary, Crew Specialties, and On-site environmental research.

5) Space Vehicles: The Space Vehicles group [6] was entrusted with the design and selection of the Space Vehicle, Vehicle Stages, Payload, Landing position. Additionally, the group worked on the technology used for the Launcher and the Spacecraft.

C. Mission Constraints

The multi-billionaire has put down a few challenges to make the quest more daunting:

- There is a no-fly zone 10 km below the peak of Mount Olympus.
- Human effort must be made towards the expedition's final moment; the last 1000 m uphill climb shall be without a vehicle.

D. Mission Profile

The total duration of the mission is 645 days. The crew stays on Mars for a duration of 25 days. The mission has been broken down into several smaller phases. Each of these phases involve a variety of technologies and is of a sequential nature. After much consideration among the subgroups, it was decided that a team of 3 astronauts will lead this expedition. Two of them would be active, i.e., they will make a summit attempt, while one passive astronaut stays back in the rover. Table I shows briefly some of the basic facts about the mission.

TABLE I
MISSION FACTS

Mission	Goal	Climb Olympus Mons
	Crew	3
	Cost	37.49 Billion USD
	DDT&E Mass	66444 kg
	L&E Mass	394383 kg
	Duration	645 days
Tantalus Crew Vehicle	Shielding	Lithium Hydride
	Payload to LEO	194920 kg
	Fuel	CH_4
	Dry Mass	15401 kg
	Crew Capsule Mass	13500 kg

E. Tasks Performed

1) Overall Coordination: Templates for presentations and reports were provided. Each member of the group was also assigned to one of the other sub-groups. They had the task of keeping the other members of the Overall Coordination group updated with developments of their respective sub-groups.

2) Mission Design: The Mission Design team utilized kernels from the NASA-made SPICE system in order to obtain data about the positions of bodies in the Solar System. The numerical data were then used in an algorithm to calculate possible trajectories. The optimal Trajectory with minimal costs and time of flight was then selected for the Tantalus mission.

3) Human Aspects: The Human Aspects team assessed the food requirements of the Tantalus mission to be 2000-2500 kcal per day per person, and water requirements of 5.5 L per person per day. Additionally, they assessed the medical aspects affecting the mission to be loss of muscle mass and increased bone fragility. Safety and countermeasures concerning shielding and fire were proposed.

4) Mars Operations: The Mars operations team formulated the hike duration to be 1 day per attempt walking for a distance of 52.2 km. The supplies were calculated to sustain for a 16 hour EVA. The weight of the Mars suit was 49 kg and the power requirements for the suit turned out to be 1120 W-hr.

5) Space Vehicles: The Space Vehicles team selected four vehicles corresponding to different stages namely Tantalus Crew Module, Crew Station, Crew capsule, Launcher. Additionally, two vehicles were attached to the Mars surface refueler and would land on Mars for refueling the crew vehicle. They designed a MATLAB code which implements the different stages of the mission. The vehicles were formulated with parameters of structural ratio and specific impulse.

III. ASSUMPTIONS

There are many constraints and unknowns for this preliminary study since there has never been a manned Mars mission to date. In order to have meaningful calculations and constructive results, beside the premises in the mission description, some important assumptions were made.

Detailed justifications for chosen assumptions are presented in each subgroups report. To give an idea on how the subgroups chose to tackle problems in this mission, the most important assumptions are mentioned in the following:

- For the Overall Coordination team, it was assumed that the development starts from 2038, after 4 years, the mission starts and sets off from earth in 2042 and come back to earth in 2044.
- For the Mission Design team [3], it was assumed that orbit maneuvers are impulsive, and no perturbations considered in the interplanetary trajectories.
- For the Human Aspects team [4], it was assumed that 3 people will go on this mission, and 90% of water consumed can be later recycled.
- For the Mars Operation team [5], it was assumed that the pressurized rover has an average climbing speed of 10

km/h, and astronauts in Mars suit have a 3km/h climbing speed.

- For the Space Vehicles team [6], an I_{sp} of 450 sec was assumed for all space vehicles, and partial artificial gravity is provided during the cruise phase.

With assumptions made, some meaningful calculations are then performed.

IV. Cost Analysis

The cost estimation was made based on the NASA Life Cycle Cost (LCC) model from [7]. This approach is suitable for the planned mission since the paper was published in 2015, and its cost estimation formula can project as far as 50 years in the future. Moreover, the LCC was developed from previous NASA missions, which also include all previous Mars missions, so the cost analysis parameters used for this mission can be quite accurate. Since the estimation tools given are simple and robust, they are assumed to be sufficient for a preliminary mission cost analysis.

The LCC estimation is comprised of 3 parts which are all heavily dependent on the mass to be delivered on Mars:

1) Design, Development, Test, Evaluation (DDT&E) and Production cost
2) Launch and Emplacement (LE) cost
3) Operation cost

The Space Vehicle subgroup together with the Mission design subgroup decided on a three-part transfer strategy, details of which can be found in [6] and [3]. One Supply Vehicle (SP) delivering around 24,700 kg. Two Refuelers (RF) delivering a total of 41,724 kg, and finally a Crew Module (CM) delivering 28,901 kg to Mars orbit. According to [6], the mass difference between staying on Mars orbit and landing on Mars is rather small comparing to the total mass orbiting in Mars orbit, so in this analysis, all the mass used is the initial mass that arrives at Mars orbit.

A. DDT&E and Production Cost

First of all, the DDT&E cost was estimated. For this estimation, a top-down approach was selected. The top-down approach evaluates the cost by applying parametric relationships from similar hardware or projects, instead of adding up each separate segment of DDT&E in the bottom-up approach.

For the top-down approach, the Advanced Mission Cost Model (AMCM) was applied. It is a long-range cost forecasting formula developed by the Exploration Programs Office, at Johnson Space Center (JSC), which is able to estimate mission cost as far as 25 to 50 years in the future. The DDT&E plus Production Cost in the unit of 1999 USD is shown in the equation below. Note that the equation has been modified for SI unit.

$$DDT\&E + PC = 9.51 * 10^{-4} Q^{0.59} M^{0.66} 80.6^{s}$$
$$*(3.81 * 10^{-55})^{\frac{1}{IOC-1900}} B^{-0.36} 1.57^{D}$$

Where

- *Q:* Total quantity of development and production units.
- *M:* System dry mass in kilograms (adjusted from pounds).
- *S:* Specifies types of mission – 2.13 for human habitat, 2.46 for crewed planetary lander.
- *IOC:* Initial Operation Capability, or the first year of system operation.
- *B:* Hardware bock or generation – 1 for new design, 2 for second generation.
- *D:* Estimated difficulty – 0 for average, 2.5 for extremely difficult, and – 2.5 for extremely easy.

For this mission, the development will start at year 2038, and it is given that by 2038, there have already been several previous manned missions to Mars. With these assumptions, parameters for the equation then can be determined.

For Q (unit quantity), Q = 1 for Supply Vehicle and Crew Module, Q = 2 for the two Refuelers. For M (arriving mass), M_{SP}= 24700 kg, M_{RF}= 41,724 kg M_{CM}= 28,901 kg like mentioned before.

Then for S (Types of mission), S = 2.46 for the crew module, S = 2.13 for Refuelers and the Supply Vehicle. For D (Difficulty), D = -1 for the Supply Vehicle and Refuelers according to the major assumption, and D = 0 for the Crewed module since artificial gravity is used, see the assumptions in [6]. For IOC (first year of system operation), IOC = 2038 for all modules. For B (hardware generation) B = 10 for SP and RF, B = 5 for CM according to [7].

And finally, assuming that the annual USD inflation rate is 3%, so that one USD in 1999 is equivalent to 2.06 USD in 2038. Then, DDT&E together with Production Cost can then be obtained for the three space vehicles as shown in Table II.

It can be seen that in spite of delivering the least mass to Mars, the Crewed Module takes more than two thirds in the total DDT&E and Production cost. This is mainly due to the specification of the manned mission and the difficulty involved with it.

TABLE II
Design, Development, Test, Evaluation and Production cost

Parameter	Description	SP	RF	CM
Q	Quantity	1	2	1
M	Mass	24700	41724	28901
S	Specification	2.13	2.13	2.46
IOC	Initial date	2038	2038	2038
B	Block	10	10	5
D	Difficulty	-1	-1	0
DDT&E and Production	Billion USD	2.01	4.27	19.11

B. Launch and Emplacement Cost

Launch cost can be rather accurately estimated. Since the launch cost to LEO orbits are well known, and with the ever booming commercial launcher industry, the price for getting things to orbit will certainly decrease dramatically in the 2030s.

Using an optimistic approach, the Space Launch System (SLS) is expected to be a success, leading to a decreased launch cost in 2038 to LEO of 5k USD/kg. Taking inflation into account the mission cost corresponds to 9.25k USD/kg.

Next, the L&E cost can be simply calculated by multiplying the cost per kilogram with LEO initial mass.

Previously in the DDT&E cost estimation, Mars arrival mass was used, and according to [7], the LEO mass can be calculated by multiplying the Mars arrival mass with a gear ratio of 6.3. However, since the Space Vehicle and Mission Design subgroups have done a thorough calculation for the total payload from LEO of this specific mission. It is then more accurate than using the gear ratio. So according to [6], the L&E are then obtained, shown in Table III.

The L&E cost is then around 1 billion USD for a single launch, which, comparing with the 2 billion USD SLS single launch cost estimation from [8] the NASA budget request, is very reasonable, and quite conservative.

TABLE III
LAUNCH AND EMPLACEMENT COST

Parameter	Values			
Cost to LEO	$ / kg	9.25		
Mass	kg	194920	199460	315600
L&E	Billion USD	1.80	1.85	2.92

C. Operation Cost

The Operation cost includes crew training, ground support throughout the whole mission, mission control and all other operational cost enabling and guaranteeing the success of the mission [9]. From previous long term programs, the operation cost can be roughly estimated as 10.9% of DDT&E and Production cost per year. With a mission duration of 650 days, which corresponds to approximately 2 years, the Operation costs were obtained (see Table IV).

D. Total Mission Cost

After obtaining all three cost components, the total mission cost can be calculated by adding up all the costs for each space vehicle and cost component. This results in a total mission cost of 37.49 billion USD (in 2038) as shown in IV. This corresponds to about 20.26 billion USD in 2021, which is around 10% of NASA's current yearly budget. So from the cost perspective, the mission is very achievable.

TABLE IV
MISSION COST

Component	Description		
	SP	RF	CM
DDR&E+PC	2.01	4.27	19.11
L&E	1.80	1.85	2.92
Operation	0.44	0.93	4.17
Total (Billion USD)	37.49		
Million USD / kg	1.078		

Furthermore, the cost to deliver a kilogram of cargo to Mars turned out to be approximately 1 million USD/kg. Comparing to the analysis made in 1996 by [9] "The cost of a human-crewed mission to the Moon or Mars is typically millions of USD per delivered kg." The cost per kilogram is still at the same order of magnitude.

To further demonstrate each component of the cost analysis, two pie charts were created for illustration. Figure 2 illustrates that DDT&E and Production cost accounts with a percentage of 68% for the largest share of the total mission cost. The overall Operation cost for the 2 year mission accounts with 15% and the L&E cost takes a share of 17% of the total mission cost.

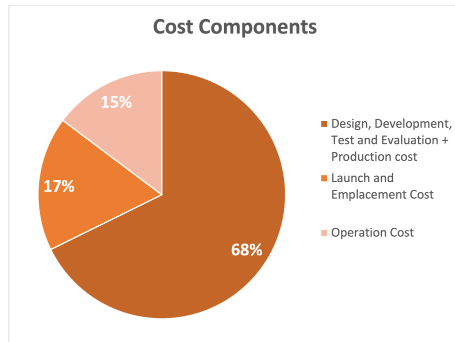

Fig. 2. Mission Cost Components

To Look at the cost from another perspective, as shown in Figure 3 below, sending the crew to Mars is the most expensive part of the mission, covering 70%. the Supply Vehicle and two Refuelers combined takes only 30% of the cost. Sending humans to Mars surely is costly.

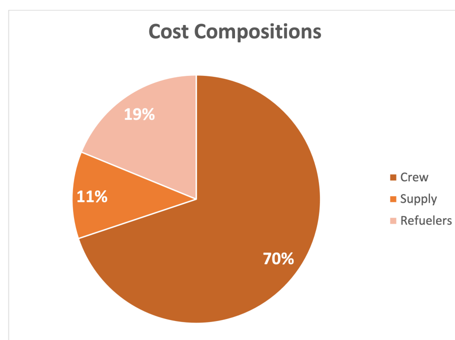

Fig. 3. Mission Cost Compositions

V. RISK ANALYSIS

This unprecedented mission tackled many technological and financial challenges. In order to address and evaluate the risks that could face the mission, a risk analysis has been carried out in a qualitative way. The mission has been divided into 4 parts:

- Launches and trip to Mars
- Mars operation
- Health of the astronauts
- Overall finance

The risks were graded according to two criteria, the occurrence probability and the consequence on the mission. These two criteria were then graded on a scale from 1 to 5. With 1 representing an event which was not likely to happen or/and with consequences that could be dealt with without too many resources. And 5 representing an event very likely to occur or/and with disastrous consequences on the mission (Lost of crew members).

A. Launches and trip to Mars

The mission was set to take place in 17 years. It was then assumed that at this time, many manned Mars missions would have already been done successfully. This had a direct impact on the level of risks for the launches and the round trip to Mars, that can be found in Table V. The launch procedure as well as the spacecraft had a good level of safety and the risk of failure was considered very low. The most concerning risk was actually the delay in the launch window for the crew launch. Indeed, in order to keep the chosen trajectory, the launch could be delayed by a few days (up to 5) with little adjustments. But, passing this date, the next launch window would have been 6 and a half years later, and the team could not afford that. It would mean extra cost and failure of the mission because competitors would probably succeed first. However, the launch window for the cargo was more flexible because there was a second launch possibility before the crewed mission, this should be enough to guarantee a successful launch.

TABLE V
LAUNCH AND TRIP TO MARS

Event	Probability	Consequence	Value
Take-off explosion crew launch	1	5	5
Take-off explosion cargo launches	1	2	2
Delay crew launch > 5 days	2	1	2
Delay crew launch > 5 days	2	4	8
Delay cargo launch	3	2	6
Failure during Mars landing crew	2	5	10
Failure during Mars landing materials	2	2	4

B. Mars operation

The most challenging part of the mission would take place on Mars ground, during the climbing of the Mars mountain. Because the team would be the first to do that, many new risks had to be taken into account. The most likely risks that could happen during Mars operation can be found in Table VI. As one can see, the most damaging events that could occur was the total failure of the rover and/or a breakdown of the communication equipment. Both could put a risk on the safety of the crew and lead to the failure of the mission.

TABLE VI
MARS OPERATION

Event	Probability	Consequence	Value
Delay in specific equipment development	2	2	4
Total failure of the rover	2	5	10
Breakdown of communication equipment	3	3	9
Mars environment contamination	5	1	5

C. Health of the astronauts

The health and well-being of the astronauts were primordial for the mission success and the risks linked to them are listed in Table VII. The worst-case scenario would be the death of members of the crew, and/or the inability to return safely on Earth. This mission is known to be long and challenging on the astronaut's body, and it was expected that they would face some physical health problems. However, with a good preparation and training, those were not likely to pose a big threat to the mission. The critical medical aspects that had to be dealt with were the development of cancers or a death induced by radiation. Those risks were limited because of the duration of the mission of 645 days and thanks to the special equipment that was going to be used in order to protect the astronauts. The most concerning risk would be the failure of the life support systems, on Mars but especially on the spacecraft. A mechanical problem preventing the astronauts from their basic needs would put an end to the mission.

TABLE VII
HEALTH OF THE ASTRONAUTS

Event	Probability	Consequence	Value
Astronaut death from disease	1	5	5
Astronaut physical health problem	4	2	8
Failure of life support system (On the Spacecraft)	2	5	10
Failure of life support system (On Mars)	2	3	6

D. Overall finance

The very high cost of this mission was estimated to be around 37.49 billion USD. The financial risks can be found in Table VIII. The main and most threatening risk was the lack of investors. This could interrupt the proper development and preparation of the mission or even cancel it if the mission is too short on money. Investors must be found and ready to invest, knowing that some extra cost could be added to the initial estimation. The second risk, directly linked to the financial

			Consequence				
			Negligible	Minor	Moderate	Major	Catastrophic
			1	2	3	4	5
	Almost certain	5	II	0	0	0	0
	Likely	4	0	I	0	0	0
	Possible	3	0	i	I		0
	Unlikely	2	I	II	I	II	III
Probability	Rare	1	0	I	0	II	II
	Total		3	5	2	4	5

Fig. 4. Priority of the risks I

part was the mission failure. If the team does not succeed in reaching the top, or the competitors arrive first, it would mean no award but above all no recognition for the mission program and the investors. This would put a threat to the future mission of the Red Team.

TABLE VIII
OVERALL FINANCE

Event	Probability	Consequence	Value
Not enough investors	2	4	8
Extra cost	5	1	5
The team does not reach the top	2	4	8
Competitors arrive first	1	4	4

E. Risk Assessment

In order to understand the value of every risk, Figure 4 and 5 record the number of risks and divide them in order of priority. Like that the team can know which of the risks are the most important and which system must be improved to reduce them. For instance for this study, the 3 highest risks were: the failure for Mars landing for the crew, a total failure of the rover and a failure of the life support system in the spacecraft.

Very high	0
High	3
Medium	8
Low	8

Fig. 5. Priority of the risks II

VI. SOCIO-POLITICAL ASPECTS

Planning a space mission is generally not only technologically demanding and associated with high expenses but also affects politics and society. The race of being the first on Olympus Mons raises not only the question of who thrives to achieve the glory and honor but also what impact such a mission will have on humankind. Therefore, it is inevitable to take a closer look at the political and societal impacts of Tantalus. Especially since these are a decisive factor on the funding strategy of the mission.

A. Political Aspects

As seen in the past, extending frontiers and manifesting power has played a major role in technology developments in space flight, promoting world powers to invest heavily into the advancement of space technology. The space race between the US and the Soviet Union during the 1950s and 1960s to achieve pioneering achievements and supremacy in space travel is a great example of how politics have affected the space industry.

Currently the race to send the first humans to Mars is a source of new innovative technologies. Only difference to the space race during the 20th century is the evolved space industry, which is now driven by private companies. The currently ongoing privatization of the space industry suggests that a race to be first on Olympus Mons around the year 2038 will be held by many private companies and not only the space agencies of two world powers. Routine spaceflights and space tourism conducted by private enterprises can have become standard by that time. However, the risks of advancing frontiers might not be bearable without the support of comprehensively experienced space agencies [10].

Since key technologies used for Tantalus are technologies from US companies and the launch site is on US soil, it is obvious that a cooperation with the US would benefit the mission. Such a cooperation in the future is considered possible since NASA is currently cooperating with privately funded commercial missions to the International Space Station [11]. Not only the US but also other countries like China or India, in which a great deal of progress can be observed in the human space programs, would most likely be interested in a cooperation with Tantalus. Since the mission must be executed as quickly as possible due to competition, choosing to have a joint mission, and cooperating with more than one government is considered to slow. Regarding the status quo, however, the US is the most suitable partner. This would mean that the mission would be completely dependent on the US, which could be critical but is considered feasible.

B. Societal Aspects

For a successful mission it is also important to draw the attention of the public. The value of the summit climb increases with the level of attention it gets. Humankind tends to be naturally curious and has been fascinated by space flight ever since Sputnik 1 in 1957. Space exploration has a big impact on culture since it inspires people to achieve the seemingly impossible and strive for more. It can foster innovation as limits of technology are pushed and the brightest people across multiple disciplines work together [10]. The landing of the first human on the Moon in 1969 united people across the world and has inspired the population cross-generational. The results of this could be seen, especially in the young generation. An above-average number of students decided to pursue studies in the engineering and scientific fields during this time [12]. With the planned mission such an impact on the new generation should be aimed for. To reignite the curiosity of the population, educational and community outreach programs should be organized. All knowledge and science gained throughout the mission should be shared with the public after a successful mission.

In order to gain the attention of the public, a well-thought-out marketing strategy is necessary, which is significantly supported by the systematic use of social media. As of today, they would enable a great platform to present the mission but will not be further elaborated in the following since media will most likely evolve over the next 17 years into something we cannot yet comprehend today. However, it is certain that the goal should be to captivate the population with the progress of the mission using media. Important part of the marketing strategy will be the involvement of the astronauts in public affairs activities. The crew is expected to be an advocate of the mission and to follow a special training to be able to meet these expectations. In general, the selection of astronauts for the mission is different from normal procedures. Due to the high risks the mission responsible are willing to take to summit Olympus Mons, the crew consists of adventurers. Each of them must be driven by growing beyond oneself and human capabilities. Determination of achieving the mission goal must be the number one priority, despite all risks.

The astronauts are aware of the risk they are taking by participating in the mission. However, the population will most likely underestimate the risks connected to such an operation. A possible incident leading to the loss of human life, would be a tragedy, stirring up discontent and distrust among the population and putting the execution of future missions in jeopardy. It becomes clear that the mission could have a comprehensive positive impact on humanity. Whatsoever a failure, depending on the extent, could undo any successes and jeopardize the population approval of future space missions.

C. Funding

To make the mission possible and have such an impact on society a lot of money is required. As the main goal requires the mission to progress quickly it is advantageous to have as much money as possible at your disposal. The funding sources can be divided into three groups: government, sponsors, and private funding.

1) Government Funding: As mentioned before, a cooperation with the US would be almost indispensable. Therefore, a possible invest from the US government into the mission should be considered. A mission success would emphasize the technological superiority of the US and could lead to economic growth like the Apollo missions did. During the past years, the budget for NASA has been around 20 billion USD which corresponds to 0.5% of the federal budget. About 45% of NASA's budget is yearly invested into human exploration, showing a high interest in this field compared to other space agencies budget divisions like ESA. ESA only spends about 10% of an already lower overall yearly budget on human exploration (see Figure 6) [13], [14]. History has though shown that the NASA budget can be increased even higher up to 4.5% of the federal budget which would correspond to date to a budget of 90 billion USD [10]. This shows that, depending on the government at the time of the mission, there is a high potential of getting governmental funds for the mission, if it is assumed to look more promising compared to competing missions. If required large parts could be financed with those funds. However, this type of funding would most likely oblige the mission to choose an American to be first to summit Olympus Mons and also make the mission dependent on the political stability of a country, as well as the arbitrariness of a president which is not always the best option. Therefore, the share of the state financial resources should be kept as low as possible.

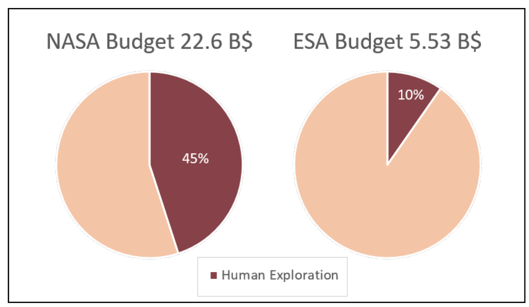

Fig. 6. Comparison of NASA and ESA division of yearly budget (2020)

2) Sponsors Funding: Another source of funding could be the cooperation with private companies as mission sponsors. To get an overview of possible levels of such an investment, the FIFA world cup 2018 was used as a benchmark. Advertising partners paid depending on the involvement around 10-100 million Euro. Selling marketing rights to companies to use for example the slogan "official partner" could bring in a lot of investments [15]. Besides advertisement partners the mission could also offer doing research during the mission in return for sponsors funds. This would benefit private companies thriving to do scientific experiments in deep space and could be part of the astronauts daily schedule. Overall a well thought through marketing strategy would be inevitable to get this type of funding and it should be carefully considered which companies to cooperate with to convey the values of the mission.

3) Private Funding: Private investors can be divided into three subgroups. The first one is professionals in the venture capital business. Those are a very reliable investors since they evaluate all risks and advantages beforehand and provide a solid source of funding. However, they usually only invest if there is a potential profit and it can be assumed that just the honor of being first on Olympus Mons will not be sufficient to convince them to invest. The second subgroup which is assumed a much better match are wealthy enthusiasts of space exploration. These investors can be expected to invest despite no economical return. Examples for such personalities are Denis Tito who paid 20 million USD to be the first tourist on the ISS in 2001 and Jared Isaacman who bought the first private SpaceX flight which will launch in 2021 for a donation to charity of 100 million USD [16]. The third and by far most difficult to estimate subgroup is crowd funding. Using the enthusiasm and euphoria of the population to collect money. Making everyone feel like they can be a part of the mission would not only help finance parts of the mission but also draw a lot of attention which is overall beneficial.

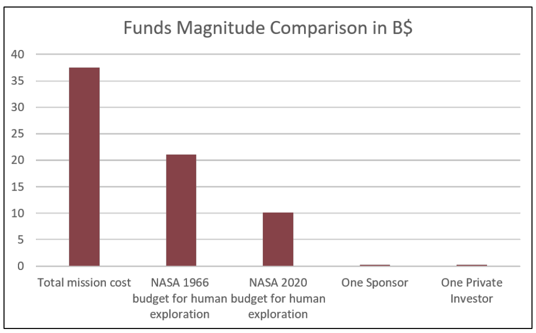

Fig. 7. Comparison of magnitude of different funding sources

Considering all the above mentioned sources it is clear that funding a mission with total cost of about 37.49 billion USD is not so easy. In Figure 7 the magnitude of some of the funding sources emphasizes this difficulty. The easiest and most reliable funding source would be finding a few private investors which would want to fully fund the mission. This option is not completely ruled out but considered rather unlikely due to the very high total investment cost, and the high risk of an unsuccessful mission. Therefore, a funding strategy with a mix of different funding sources is considered most effective as this would spread the risk over several groups. First step of the financing should be getting as much capital from private investors and sponsors as possible. Goal should be to finance a major part of the mission with those investments only using US governmental funds for the unfunded portion of the costs to remain as independent as possible from the state. Another part of the financing strategy should be involving the population through crowd funding. The income from these funds is difficult to estimate, as it depends on the general mood within society and the economic situation. This uncertainty could be compensated by aiming to raise more money than necessary, promising all investors to not only give the prize of 100 million USD but also all not required funds to charity. Using space missions to collect and donate money to charity has become more popular and is a good way to attract attention to the mission with not only exploring the unknown but also doing good on earth.

VII. Project Management

Managing a project with several subgroups and an overall count of 22 team members requires coordinated communication and structures to guarantee a coherent project outcome. It is mainly important to ensure a consistent information flow between all subgroups. Therefore, different work methods were implemented in the project work of Team Red to use the scheduled project hours as efficiently as possible.

A weekly all Team Red meeting, led and documented by the Overall Coordination group, was made mandatory. The meetings served the purpose of the subgroups updating each other about their work progress, inputs they require from other groups and setting goals for the week. Also made assumptions within the groups were shared and decisions concerning the whole team made, following the main goal of maintaining consistency within the mission design and concept. Most important output of the first two meetings was the creation and agreement on a Work Breakdown Structure shown in Figure 8, containing the main tasks and responsibilities for each subgroup and serving as basis for the mission planning. Besides the all Team Red meeting each subgroup was expected to have at least one additional meeting per week to focus on group internal tasks. To keep track on the discussion and progress, writing and sharing meeting minutes was made mandatory for all groups.

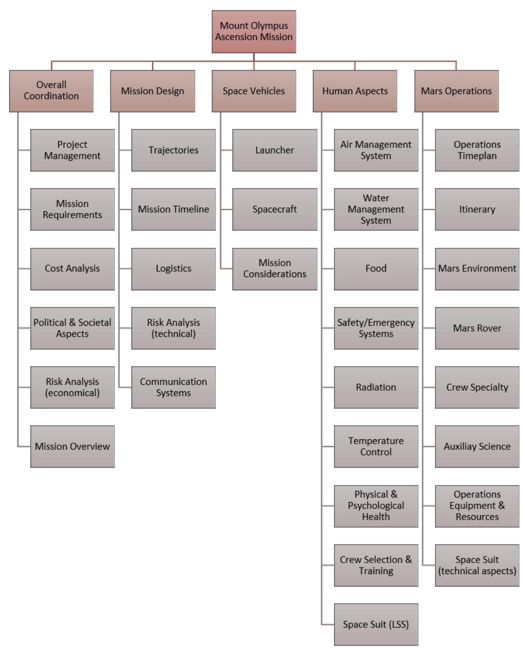

Fig. 8. Work Breakdown Structure Team Red

Throughout the project each team member of the Overall Coordination group worked together closely with an assigned subgroup, following up on their work and updating the other Overall Coordination members regularly about the progress. The specific responsibilities can be seen in the organizational chart in Figure 9. Alongside following up with the planning process of the subgroups, main tasks of Overall Coordination were defining the mission requirements and constraints in agreement with all groups. Also identifying conflicts and helping with solving them was part of the tasks to ensure a cooperative teamwork and reaching a common goal. To make a uniform appearance as Team Red and save work for each subgroup the Overall Coordination group also provided templates for the report and presentation which were supposed to be created by each subgroup separately.

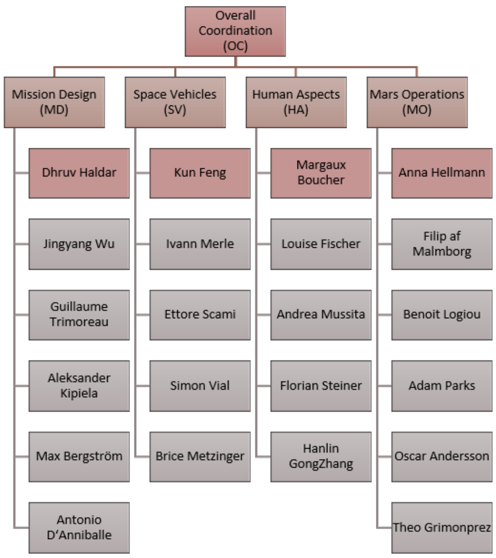

Fig. 9. Organizational Chart Team Red

For a successful project, fast communication within the groups and the whole team as well as sharing information is crucial, especially taking into consideration a relatively short project period. Therefore, various online platforms were made accessible for all team members and used throughout the mission planning process to facilitate efficient team work:

- *Slack* – A work space for Team Red was created on the communication platform with general channels for announcements and zoom meeting links as well as channels for the different subgroups to enable frequent and easy communication between all team members and subgroups.
- *Google Drive* – A folder for Team Red was created containing folders for each subgroup to share documents with the whole team like the mandatory meeting minutes. Also simultaneously working on documents is possible on this platform, enabling efficient collaboration.

VIII. Conclusion

In cooperation of five subgroups and with the help of well-founded assumptions, a Mars mission with a crew consisting of three adventurous astronauts could be planned, whose goal was the first ever ascent of Olympus Mons. The technologies required for the Tantalus mission have been estimated based on current and near future developments, resulting in a mission duration of 645 days and a stay of 25 days on Mars. The total cost of Tantalus, whose development will start in 2038, was estimated at 37.49 billion USD after extensive cost analysis. With such high total mission cost, a financing strategy was developed based on the best possible distribution of financing risks and the greatest possible financing security. In addition, a comprehensive analysis and evaluation of risks was carried out, the result of which confirms an acceptable number and amount of risks. Finally, it can be stated that in view of the results of the case study, a manned Mars mission and the ascent of Olympus Mons in 2043 is considered feasible with political and societal support.

IX. Acknowledgments

Coordinating a project of this size was a completely new challenge for us as Overall Coordination subgroup and we would like to take this opportunity to thank the entire Team Red for the good cooperation and the successful completion of the project. We would like to acknowledge our mentor Nils Pokruba, who supported and guided the whole team with his expert advice. And also thanks to our professor Christer Fuglesang, whose lectures broadened our knowledge about human spaceflight and future missions to Mars, and our teaching assistant Anna Larsson, whose advice and tips from her own experience helped our group throughout the project.

X. Division of work

Besides a shared responsibility for ensuring cooperation between all subgroups of Team Red, the tasks of researching and writing of the report were divided as following:

- *Margaux Boucher*: Worked on gathering information from all subgroups about risks of the mission and developing the risk analysis.
- *Kun Feng*: Responsible for method selection and implementation of the cost analysis, summary of the assumptions and creation of the mission logo.
- *Dhruv Haldar*: Worked on gathering information from all subgroups to create a mission overview.
- *Anna Hellmann*: Responsible for developing a funding strategy, illumination of the sociopolitical aspects of the mission and the written definition of the project management approach.

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