Low Mass Mission to Mars
Blue Team - Project Management Report

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***Abstract*—Interplanetary missions to our neighbour planet Mars are by now a very tangible goal of many space agencies, both private and governative ones. The main focus, however, seems to be the *colonization* of the "Red Planet", by sending more than one space vehicle at the time, each carrying tens of humans. This report, which is part of a complete study, examines the factors and designs the context of a low mass mission to Mars, on behalf of the company Pythom Space, with the purpose of sending just Tina and Tom Sjögren, the two founders, on an exploration journey to the planet. The mission objectives and restraints will be analyzed, and a mission summary will be given. Moreover, fundings and costs will be estimated, and the social and political aspects will be investigated, along with the risks of such expedition. An off-nominal scenario, as well as the management process of the Blue Team, will conclude the paper.**

***Index Terms*—Interplanetary, Human Spaceflight, Mars, Martian expedition, Crimson**

I. Introduction

A. Mission Denomination

The mission is called Crewed Redurn Interplanetary Mission for Surface Operations and New research, C.R.I.M.S.O.N. for short (which is also a shade of red, thus reminiscing of the famous color of Mars' regolith). The choice was to design an evocative yet simple logo (Figure 1), including both the Red Planet's profile on the top and, playing with the negative spaces, Pythom Space's eagle flying over it. A visual representation of Chandor Chasma valley, the planned landing site, has also been added on the background.

Fig. 1. Mission Logotype

B. Mission Description

The mission is the project of the course SD2905 - Human Spaceflight at KTH Royal Institute of Technology in the Spring 2022 semester. The purpose of the mission is based on the idea of a startup company *Pythom Space*. The technology and the cost for the mission are based upon the current products available in the present time and the extrapolation of technology in the future before the launch planned in 2026.

C. Mission Objectives

The primary objective of the mission is to design a simple and low-mass human mission to Mars. The idea of simple and low-mass came from *Tina and Tom Sjögren*, the founders of *Pythom Space*, as similar to their experience to Mount Everest, North and South Pole with minimum gear and light-weight equipment. The project is proposed to launch within the next five to six years. Furthermore, the main purpose of the human mission to Mars is for exploration and discovery only.

D. Subgroup Objectives and Tasks Performed

As the Blue Team has 33 members, the team is divided into six subgroups - Overall Coordination, Mission Design, Logistics, Transfer Vehicle, Mars Operations, Mission Design and Human Aspects. Each subgroup has its own objectives and tasks. Since some part of the mission has an overlap between each subgroup, a meeting was held at the start of the project to ensure that there are no overlapping parts among subgroups and the workload is divided equally. Moreover, each subgroup is instructed to come up with a different off-nominal case and the suggested solution to the problem.

1) Overall Coordination: The objective of the Overall Coordination group is to lead and manage the communication within the Blue Team and to ensure that all members are working towards the same direction. In addition, the Overall Coordination is responsible for the management, finance, risk analysis and social aspects of the mission, as well as coming up with templates for the report and presentation of the Blue Team.

2) Mission Design: The objective of the Mission Design group is to plan the mission schedule and design the trajectory of the vehicle from start to the end of the mission, which is from the first launch towards the return to Earth. Therefore, the group is responsible for calculating the launch date, speed, orbit and how to re-enter the Earth.

3) Logistics: The objective of the Logistics group is to design the systems of the mission which includes the thermal control, communication and power supply system. The task also includes the assembly system in LEO as well as the launch schedule and the maintenance system on the transfer vehicle.

4) Transfer Vehicle: The objective of the Transfer Vehicle group is to design the transfer vehicle and the mass budget for the whole mission. In addition, the group is responsible for mapping each part in the transfer vehicle, which consists of the habitat, node, power and thermal control system, propulsion system, and the power system.

5) Mars Operations: The objective of the Mars Operations group is about the activities and tasks on Mars for the crew. The group is responsible for the design of living habitat on Mars as well as the descending and ascending vehicle from the transfer vehicle to Mars surface. During the mission on Mars, the group has to plan the schedule for the crew, design the space suit, together with what research has to be done, and how the communication will work on Mars.

6) Human Aspects: The objective of the Human Aspects group is to handle the life support systems for the mission, as well as the astronauts training and the medical aspects inside the transfer vehicle. The design of life support systems includes the sizing of water, air, food, supplies, hygiene and waste management.

E. Mission Constraints

The constraint for the mission is taken from the project instructions as well as the meeting that the team has with Pythom Space regarding the mission. As a result, these are the constraints that are known among each subgroup in the Blue Team:

- The mission will have 2 people onboard of the spaceship, which are *Tina* and *Tom Sjögren*.
- *Kang launchers*, the launcher created by Pythom Space, will have to be used.
- The transfer vehicle will be assembled in LEO.
- The chance of success for the mission has to be higher than 75%.
- The chance of death for the crew members onboard has to be less than 3%
- The mission will not involve the government from any country.

II. Mission Summary

In this section an overall mission summary is given. A high level description of the whole operation is presented, focusing on the work done by all the groups.

Several transfer and parking orbits, from, to and around the Earth and Mars, were analyzed by Mission Design [1]. The definitive choice has then been set on two conjunction transfer orbits, starting from LEO and arriving to Mars with an elliptical orbit, in order to lower the total ΔV. The mission starting phase, including all the launches to LEO and in-orbit assembly (designed by the Logistic team [2]) of the transfer vehicle (conceived by the Transfer Vehicle team [3]), is set between November 2024 and October 2026. From here, the Earth-Mars transfer trajectory will last 304 days, reaching the destination on August 2027. Thereafter, the transfer vehicle will orbit Mars for a grand total of 368 days. During this time period, two Mars Descent Vehicles (MAVs) will land on the planet. The first will carry goods and materials necessary for the survival of the astronauts (like food, water and the Life Support System, all sized by the Human Aspects team [4]), the latter the astronauts themselves. Tina and Tom will then inhabit an inflatable habitat for a period 23 days, at the end of which they will ascend to dock with the orbiting transfer vehicle. On the surface, the two astronauts will follow a schedule designed by the Mars Operations team [5], including four EVAs aimed at canyon explorations and some scientific research. After the ascent, they will then be able to insert the Mars-Earth orbit trajectory at the end of the aforementioned 368 days. This trip will start on July 2028 and will take 336 days, reaching destination on July 2029. They will then perform a skip reentry trajectory to finally touch the Earth with a splashdown.

III. Funding

A human expenditure mission to Mars is definitely a high-caliber mission with huge impacts on various aspects. For certain, a large amount of money is needed for a mission of this scale. Moreover, the mission is decided to be completely private, thus, there will be no funding contributed from the government at all which is typically the main channel for most space mission funding. On the contrary, the mission is also especially designed to be a simple low mass mission which minimizes the cost; therefore, the mission is still feasible even though there is no government involvement. The funding channels comprise of three groups: broadcasting and sponsorship, private funding, and other funding.

A. Broadcasting and Sponsorship

As the government funding is not an option for this mission, other channels of funding must be sought to make the mission possible; otherwise, Pythom Space would be the sole source of funding for the whole mission. One of the promising sources which could provide a large sum of money is to form partnership with companies worldwide, in other words, a sponsorship.

Mainly, broadcasting companies will be the main target as the mission involving the first human mission on Mars would attract high public attention. The live streaming of the moment when Tina and Tom landed on Mars or during the expenditure at the Candor Chaos canyon would be perfect moments suitable for broadcasting to the whole world. In terms of funding, broadcasting rights will be given to partner broadcasting companies which gives them rights to broadcast live moments from Mars on their channels. In order to gain an expected value of funding from broadcasting, the value from two major global sport events, including FIFA World Cup and Olympics, will be used as benchmarks. For the latest FIFA World Cup held on 2018, FIFA earned $2.972M from broadcasting rights alone [6]. As for the Olympiad spanning 2013 to 2016 including the Olympic Winter Games Sochi 2014 and the Olympic Games Rio 2016, the International Olympic Committee (IOC) raised $5.7 billion where 73% of the revenue belongs to broadcasting rights which is $4.161M [7].

Apart from the broadcasting rights, non-broadcasting companies could also be the mission's sponsors via marketing rights which basically gives partners rights to claim a title of "official partner". Marketing strategies could be deployed to attract as much companies as possible, for example, companies with high contribution will receive special honor such that their logos will be painted on the Mars Descending Vehicle (MDV) surface which will be left on Mars even after the mission. Similar to the broadcasting rights, the estimated funding obtained via selling marketing rights could be approximated from the FIFA World Cup and Olympics. In 2018, FIFA gained around $1.660M from marketing rights [6]. As for the 2013-2016 Olympics, 18% of the revenue contributes to the marketing rights which is equivalent to $1.026M [7].

By combining both broadcasting rights and marketing rights, the expected funding from this source would be $4.632 billion and $5.187 billion estimated from the FIFA World Cup and the Olympics respectively.

B. Private Funding

Even though the income from broadcasting and sponsorship alone would easily cover the entire cost of the mission, other sources of funding must still be considered in cases where some unexpected events occur. Another promising source of funding would be private funding where it could be divided to 3 groups including Pythom Space, private companies, and space enthusiast billionaires. Firstly, as the owner of the mission, it is obvious that Pythom Space will be the one who contributes to the funding themself. According to the meeting with Tina and Tom, the budget of $500M was mentioned, hence, it is safe to assume that the funding of at least this amount is expected from the Pythom Space. Secondly, some private companies who are interested in the mission and would like to be a part of the mission could provide financial support to the mission as well. Lastly, space enthusiast billionaires could provide large portion of funding for the mission rivalling the amount obtained from broadcasting and sponsorship. Currently, there are eight candidates who might be the mission's grand sponsors where the most promising candidates are Elon Musk and Jeff Bezos [8]

C. Other Funding

Other than the mentioned sources of funding, some other possible channels of funding do exist including, but not limited to, crowdfunding, film making, merchandise, etc. Firstly, crowdfunding, donation, or fundraising event are typical channels for one to obtain some funding. In fact, Pythom Space already initiated this where people who are interested can donate via their website [9].

Secondly, the actual footage from the expenditure on Mars or the invaluable experiences from the first two human on Mars could be made into a movie or documentary film. This way, the mission could expand the sponsorship opportunity to movie industry where the actual footage and story from two astronauts will be exchanged for some sort of funding. Lastly, merchandise could also be made to be sold globally with or without helps from other companies. Moreover, actual items onboard in the mission returning from Mars could also be sold or auctioned at the end of the mission.

IV. Mission Cost Estimation

1) Development of Kang Launcher: The formula given by [10] is used here to determine the Design, Development, Test and Evaluation (DDT&E) cost and production cost of the Kang rocket.

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

With Q being the quantity built, M the dry mass to bring to LEO, s a coefficient depending on the type of mission (2,46 for a crewed launcher), IOC (Initial Operation Capability) the first year of operation, B the hardware bock or generation and D the difficulty.

TABLE I
DDT&E PRICE

Coefficient	**Value**
Q	10 (7 + 3 test rockets)
M	3 Tons
s	2,46
IOC	2026
B	1
D	0 (medium difficulty)
Total Cost	930M$

The total cost to develop the Kang launcher is 930 M$, which is in the range of order for the development of a new expendable rocket.

2) Launch Vehicles: The launches to bring all the materials for the construction of the transfer vehicle to LEO [11] are going to be made with:

- 6 Kang launchers (Pythom Space);
- 1 Falcon 9 expendable launcher (Space X);
- 1 Falcon 9 reusable launcher (Space X);
- 4 Falcon Heavy launchers (Space X).

Based on Tom & Tina's predictions, the cost per kilogram of payload to LEO of Pythom Space's Kang launcher is going to be 1 k$/kg. For this mission, a less optimistic value of 2 k$/kg was considered. Assuming a payload capacity of 3 tonnes, the total cost for each launch at full capacity is 6 M$.

The cost per launch to LEO of an expendable Falcon 9 launcher at full capacity is 60 M$ [12] ($\sim$2.6 k$/kg), while for the reusable version of the launcher is 50 M$ ($\sim$2.9 k$/kg).

Furthermore, Falcon Heavy has a cost per launch to LEO of 150 M$ [13] (∼2.3 k$/kg).

The total cost for all the launches to LEO is then 746 M$.

3) Transfer vehicle: The transfer vehicle is an important part of the convoy, as it will bring Tina and Tom from Earth to Mars and back. It needs to be comfortable enough to live inside for more than 2 years. The only example of transfer vehicle ever built is for the lunar missions. Back in 1969, its development cost was estimated to be 750 M$. Taking into account inflation this price would today be 1250 M$. Nowadays, we can assume that with technology improvements these last 60 years, the costs reduced. On the other hand, this transfer vehicle would be bigger and used for a longer time than the *Columbia* transfer vehicle. For these cost estimation, it has been assumed that these two facts were balancing each other. The final price of the transfer vehicle is now 1250 M$.

4) Operations: The operations costs, which include the astronauts' training, mission control and salaries of the employees, as well as other indispensable costs for a successful mission, can be approximated as 10.9% of the total development and production costs per year [14]. Hence, given that the mission duration is estimated to be around 1000 days, or 2.7 years, and the total costs amount to 930 M$, the operation cost is 274 M$

The rest of the costs listed in Table II refer to real life technologies, specified inside the brackets, and their current prices. In particular, for the Life Support, a particularly high estimated price is given (outlined from [15]), assuming a high level system capable of reaching a nearly *circular economy* and adding a safe margin to the expense.

TABLE II
COST BREAKDOWN

Item	Cost (Million $)
Kang launcher development	930
Kang launches	36
Falcon 9 expendable launch	60
Falcon 9 reusable launch	50
Falcon Heavy launches	600
Operations	274
Life Support System [15]	800
Mars Habitat (Bigelow Aerospace's BEAM module)	100
Drones (NASA's Ingenuity drone)	30
Total	2880

V. SOCIAL & POLITICAL ASPECTS

The sociopolitical aspects of a human mission to Mars are widespread and could have an impact on society in many ways. In this segment, the foreseeable effects are discussed based on the outline of Pythomspace's vision of the human mission to Mars. Thus, the mission will take place within the next 5-6 years, hence putting the first human on Mars. NASA's plans to send the first human on Mars with the help of private investors will not take place until mid-2030. Also assuming that the mission will be carried out with the help of private investors and help from the US government regarding launch regulations and permissions.

A. Political

The level of government involvement will clearly play a role in how the political landscape is affected by the first human mission to Mars. The governments' incitement to be involved in such a mission is increased support from voters by being remembered as supporting human exploration and advancement of society. [16] However, government spending time and personnel equal funding from taxpayers, which can arguably be controversial. One could question the investment of space exploration with the many challenges and suffering humanity faces on Earth such as starvation, poverty, and violence. This is why an information campaign would be relevant as to not let conspiracies and undermining the approval of the government affect scientific progress. The information campaign should promote how investing in science is investing in the betterment of humanity, and how one could avoid being short-sighted about this topic. [17] In today's space industry, joint funding from private companies and investors and the government is most likely to be the standard of space investments. Thus, the profiling of the private companies will have an impact on how the government is perceived by the public.

With advancements in space comes competition between nations, and the modern-day space race is back on track. The big nations currently competing for the winners' title are China, Russia and the US. [18] To have an unexpected nation like Sweden to be involved in putting the first humans on Mars would come as a surprise to the world, but maybe for the better. As tension between the three super-nations is fluctuating, it might be preferable if none of them won the race as a solo competitor, and hence benefit a globalist approach.

B. Social

Continuing on the topic of globalism and nationalism, could space exploration and a human mission to Mars lead to one or the other, or both? One could argue that the global efforts to pursue space programs feed a new type of nationalism via power projection common to military exercises. [19] On the other hand, globalism is the leading trend that replaced the cold war, and space activities are likely to influence the spread of globalism. [20] A perfect example of such an activity is the International Space Station, where many nations have come together to solve complex problems for a common goal of space research. [21]So a human mission to Mars will hopefully inspire joint global efforts that will further cement the idea of globalism on Earth and beyond.

A consequence of the exploitation of Mars is bringing the concept of capitalism out in our solar system. Turning Mars into a commercial place might have social consequences. Capitalism is partly based on infinite growth, on a finite planet. It's shown that the dynamics of capitalism pushes society towards materialistic goals, and underestimates goals essential to life quality, such as care and creativity. [22] One might even suggest that capitalism is the root of climate change and that capitalism is not a sustainable economic model. [23] This is to have in mind when private investors and sponsors are mostly responsible for the investment in this human mission to Mars, and sets the tone for how we will develop an economic model in outer space.

There surely be all kinds of reactions from people all over the world when the first person(s) set foot on Mars. In today's society, inclusivity is crucial in all kinds of projects. There's suggestions that the first person on Mars should be a woman. It's been more than 50 years since Russia sent the first woman to space, over 40 years since NASA selected the first female astronaut, and still, no woman has been on the moon. [24] In such a male-dominated field of science, and in engineering in general, there is definitely women representation needed in order to make science more diverse and creative. According to NASA administrator Jim Bridenstine, the first human on Mars is likely to be a woman. [24] This also brings up racial issues. Sending only white people on the first human mission to Mars can be seen to be un-inclusive since we're used to seeing people of color not being represented in our history books. To phrase Douglas Adams, British author; "Space is white. You just won't believe how vastly, hugely, mind-boggling white it is". In addition to that, it is male-dominated, where women in space fiction are often portrayed as rather sexy than smart engineers. [25] People of color have been, and still are, marginalized for years, and the field of engineering and space is, unfortunately, no exception. In order to make space exploration for the whole human species, one might reconsider sending an all-white crew as the first explorers of the human race to Mars.

C. Legal

There has recently been controversy whether Mars is a "free planet" or not by statements from SpaceX. In a statement SpaceX says the following: "For services provided on Mars, or in transit to Mars via Starship or other colonization spacecraft, the parties recognize Mars as a free planet and that no Earth-based government has authority or sovereignty over Martian activities". This is however not correct since all international laws apply in outer space and also on celestial bodies including Mars, according to the Outer Space Treaty, signed by 111 countries in 1968. [26] In short, the Space Treaty says that no state can take national appropriation of a celestial body, each state is responsible for avoiding harmful contamination and ensuring that the exploration of outer space is for the benefit of all mankind. [27] The question of ownership and national borders on Mars should be dealt with in the form of a constitution to complement the Outer Space Treaty. This should be done before any nation plants its' flag on the surface of Mars, since, if we were to settle on Mars it would be a multi-national effort. [28]

Another legal agreement in place is the Rescue and Return Agreement. Signed in 1972, it briefly states that the states are bound to report any dangers to the crew of manned spacecrafts, and to rescue and safely return all personnel. This also includes manned spacecrafts that lands in a state that was not the launching state. [27]

Another point is the exploitation of Mars, both concerning the mining of minerals and soil, and the effect of the Mars environment. Looking at the devastating impact mining has had on the surrounding environment on Earth, one should be careful not to make the same mistake on Mars. As of now, Mars is yet to be considered a life-less planet. However, we can not completely rule out the possibility of life on Mars, and thereby there need to be regulations about how we avoid to contaminate the planet. We do not want to extinct the only lifeform to yet be discovered besides from planet Earth before we had the chance to observe it. [28] This means that when humans go to Mars, there should perhaps be extended regulations in place about how there could be exploitation of the soil, and how it can be guaranteed that no lifeforms from Earth will spread on Mars uncontrollably.

VI. Risk Analysis

During the mission, any unprecedented events can occur at any time. Therefore, in order to prepare for the risk that could happen, the risk analysis presents a viable approach to predict what could happen and be prepared for the impact. Therefore, the team laid out all of the events of failure or malfunction that can take place throughout the mission. For simplicity, the mission is divided into six phases:

- Production
- Launch
- Assembly
- Transfer
- On Mars
- Re-Entry

In total, there are 25 events that are listed by the group. A score is given by the team for each event on a scale of 1 to 5 based on two criteria: possibility, the chance of the event to occur, and impact, the severity of the event. Regarding the score, 1 represents the least chance for the event to occur or/and the least severity of the impact, while 5 represents the event with the most likelihood to occur and/or the most severity of the impact on the objective of the mission. Each score given is determined from the research on historical events, as well as the extrapolation of the current technology regarding the event, t In the end, the value is obtained by multiplying the possibility score with the impact score of each event. Thus, these values represent the chance of failure of the mission, which can then be used to calculate the chance of success of the mission further.

TABLE III
Production

Event	**Possibility**	**Impact**	**Value**
Delay in Supply Chain	3	2	6
Overshoot Budget	4	2	8

TABLE IV
Launch

Event	**Possibility**	**Impact**	**Value**
Explosion of the Cargo Capsule	1	4	4
Explosion of the Crew Capsule (fatal)	1	5	5
Bad Weather Delay	1	1	1

TABLE V
ASSEMBLY

Event	Possibility	Impact	Value
Malfunction of Small Thrusters	2	3	6

TABLE VI
TRANSFER (IN SPACE)

Event	Possibility	Impact	Value
Malfunction of Solar Array	2	4	8
Malfunction of Life Support Systems	1	5	5
Malfunction of Transfer Vehicle	1	5	5
Health/Mental Health of the crew	2	3	6
Failure of Communication	1	3	3
Malfunction of Propulsion System	1	5	5

TABLE VII
ON MARS

Event	Possibility	Impact	Value
Malfunction of Inflatable Habitat	1	5	5
Failure of 1st MDV	2	3	6
Failure of 2nd MDV (fatal)	1	5	5
Failure of Life Support System	2	4	8
Failure of MAV (fatal)	1	5	5
Malfunction of Solar Array	3	3	9
Occurrence during EVA	1	2	2
Failure of Communication between Astronauts	1	2	2
Failure of Communication between Astronauts and Ground Station	1	2	2

TABLE VIII
RE-ENTRY

Event	Possibility	Impact	Value
Failure of Life Support System	1	5	5
Failure of EDV (fatal)	1	5	5
Failure of Communication	5	2	10
Malfunction of Propulsion System	1	5	5

TABLE IX
RISK MATRIX

		Impact				
		1	2	3	4	5
Possibility	5	0	I	0	0	0
	4	0	I	0	0	0
	3	0	I	I	0	0
	2	0	0	III	II	I
	1	I	III	I	I	X

After determining the possibility, impact, and value of all events, the risk analysis (see TABLE IX) can be constructed to display risk of the mission. The level of importance of the risk is classified into 4 levels, from low risk in the green cells, medium risk in the yellow cells, high risk in the orange cells, to very high risk in the red cells. From 25 events, the mission has to be in caution of mainly 2 events in the high risk zone, and 14 events in the medium risk zone. There is no event that has been considered as a very high risk event in the mission. In addition, the team has considered 4 events to be fatality events, which is the risk that could lead to the death of one or all crew members. These events are the explosion of the crew capsule, failure of 2nd MDV, failure of MAV, and failure of EDV, as labeled as fatal in TABLE IV and TABLE VII, and TABLE VIII.

As two of the requirements for the mission are the chance of success and risk of death of the mission, the group has used the risk analysis table to calculate both requirements. The calculation follows a simple logic, that is the chance of success is an inverse of the chance of failure while the risk of death is the chance of failure of fatal events.

Therefore, since the chance of failure has already been calculated in a scale of 1 to 5 already, the chance of success is the inverse of them on 1 to 5 scale as well. Therefore, for the risk of death, only 4 fatality events are used to calculate the risk of death. Specifically, the chance of success and risk of death can be calculated using:

$$chance\_success = 1 - chance\_failure$$

which is equivalent to:

$$chance\_success = 1 - \Sigma value$$

and

$$risk\_of\_death = \frac{\Sigma value(fatal\_events)}{chance\_success + chance\_failure}$$

TABLE X
CHANCE AND RISK REQUIREMENTS

	Requirement	Value
Chance of Success	>75%	80%
Risk of Death	<3%	2%

As a result, the chance of success and risk of death are calculated to be 80% and 2% respectively. Both numbers pass the criteria set by Pythom Space as shown in Table X and therefore can be concluded that the mission can proceed without any problem.

VII. OFF-NOMINAL SCENARIO

A. *In the Event of a Deadly Accident*

Dealing with human missions, the management of failure becomes more crucial than ever. A scenario that would affect the whole mission would be the event of a deadly accident, involving one, or both of the astronauts. This is especially relevant with the increasing amount of manned missions to space. As the pioneering mission to Mars, this case needs to be considered in order to not set-back future exploration of Mars.

B. *Procedures*

Looking back at the space shuttle challenger disaster, where all seven crew members were killed 73 seconds into flight. This, of course, had a huge impact on the space industry and public opinion. [29] That is why a crisis management protocol should to be in place in case of a fatal disaster. A lesson that could be learned from the Challenger disaster is the level of transparency. After the disaster, NASA was criticized for not making information available to the press, resulting in conspiracy theories, lacking evidence, spreading in media.

Other crisis management procedures that were in place were a prepared speech by the president of the United States and an independent investigation after the disaster. [29] This could perhaps form the outline of how Pythomspace should respond to a failure of the same magnitude as the Challenger disaster.

C. Broadcast and sponsors

Since there will be a live broadcast during critical phases such as launch, landing and living on Mars, there needs to be a solution on how to avoid an accident being streamed. There's multiple ways to solve this problem. One suggestion could be that the broadcast could be monitored and reviewed by professionals during a 20 minute delay, before the material arrives to streaming platforms. Another one could be that the broadcast is synced with the health monitors of the astronauts. Once one parameters hits a critical value, the broadcast could be automatically terminated.

Dealing with sponsors is a bit trickier. The first step would be transparency regarding the risk assessment and how the mission is designed to keep risk of failure at at minimum. However, the risk for failure can never be zero. This concludes that the sponsors would have to evaluate how their brand would be, if at all, affected by a mission failure and if they are willing to sponsor the mission after receiving the risk analysis.

Since this mission will be without funding or research provided by any official institution, any casualties would perhaps have a greater impact on the associated companies and private investors. For comparison, Jeff Bezos' "Blue Origin" had its first launch with the Amazon CEO among the crew in 2021, with many emergency systems in place. Parts of the emergency system is an escape pod that will be ejected from the rocket in case any abnormalities are detected. [30] It goes without saying that if Jeff Bezos would happen to be in a fatal accident during launch, there would be great effects on Amazon.

In case of failure, an additional statement could be made, making clear that the cause of the accident is not afflicted with any sponsors.

D. Pursuing the C.R.I.M.S.O.N. mission

In the case where one of the astronauts would not survive, the conditions for pursuing the mission would be very harsh. Regarding life support, the surviving astronaut would have plenty of resources to carry on the mission and to get safe back home. However, some activities have an increased risk of failure being performed alone. For example, EVAs' would have a higher risk of failure due to lack of direct communication with the other astronaut in case there would be need for immediate response and help. Other tasks would be more time consuming, such as building the habitat and don and prepare the spacesuits. Concerning the psychological factor of, in this case, losing your spouse, the mission surely could not be continued with the same priorities as before the accident. It is suggested that the priorities after such an accident is to get the remaining astronaut home as soon as possible from the current position in space.

In case of a accident where both astronauts die, there is little that can be done to continue the mission. If the installment of CUBE satellite [1] and drones [5] have been done successfully, there is still some data that can be retrieved and analysed after there are no astronauts left for further exploration.

VIII. Project Management

The Blue Team consists of 33 members divided into 6 subgroups; hence, managing this large group to work together efficiently and in the same direction is challenging. The main concerns are to avoid conflicting assumptions or calculations and to ensure consistent flow of information between each subgroup. Therefore, this section will include different methods implemented to manage the whole Blue Team efficiently.

Firstly, the Blue Team weekly briefly meeting will be held with the entire team at every Wednesday. Each subgroup has three minutes to announce their work progress according to three simple questions: what you have done since the last meeting, what are you going to do this meeting, and what will you do this week. By doing this, the entire team, including every member, is updated with each subgroup's progress. Moreover, the three brief questions are also being made into meeting minutes template for the Blue Team to be used for every meeting held internally by each subgroup.

Secondly, the overall coordination team also requires each subgroup to nominate one representative who will be responsible for communication and coordination between each subgroup. For instance, if one subgroup would like to discuss something with another subgroup, this can be done between their representatives instead of holding a meeting between the two subgroups. Furthermore, there were several meetings involving the overall coordination team and representatives aiming for updating the work progress, requesting information required from other subgroups, discussing for overlapping responsibilities, etc. Additionally, a member of the overall coordination team also has responsibility over the assigned subgroup as well, i.e., one member from the overall coordination team will be responsible for one of the subgroups. However, the subgroup a member is responsible for will change weekly so that a member will have a chance to work with every subgroup of the team.

Thirdly, in order to streamlining the process of requesting information from other subgroups, a Request Form and Responsibility Area was created via Google Spreadsheets. Each subgroup will have their own sheet consisting of two sections: request form and responsibility area. A request form is where other subgroups will write questions requesting answers from that subgroup while the responsibility area is where the subgroup will write every topics that they will work on so that each subgroup can crosscheck whether their responsibilities are overlapping.

Lastly, in order to ensure efficient communication and information sharing, two online platforms were used including Slack and Google Drive. Slack was used the main communication channel for the entire Blue Team or between some team members; for example, there is a general channel dedicated for the whole team, six subgroup channels for each subgroup, a representatives channel for communication between the overall coordination team and the representatives, etc. Google Drive is dedicated for information sharing for the whole group; therefore, all documents of each subgroup are made accessible for all team members including the meeting minutes. Furthermore, templates for report, presentation, and meeting minutes as well as the request form and responsibility area spreadsheets are being distributed via the Google Drive.

IX. Conclusions

The C.R.I.M.S.O.N. mission, as designed by the Blue Team, advances an outline of the technical solutions of sending the first two humans on Mars, with an overall low-mass constraint. The mission, including the in-orbit assembly of the transfer vehicle, will last a period of about 4.5 years.

The idea of a privatized nature behind this mission sets decisive limitations on the public national budgets, but at the same time opens the door to private investors to finance such humanity milestone and allows the company designer of this project to not undergo certain restraints set by governments.

On a final note, it is worth noticing how, with the restrictions set and taking for granted a technological advancement as rapid as it has been in the last years, it could be in fact possible to achieve the goal of a short-stay mission on Mars as pitched in this research project.

X. Workload Breakdown

A. *Jacopo Carra*

Sections written: Abstract, IA, II, IV2, IV4, IX.

B. *Karanit Ketsumpan*

Sections written: IB through IE, VI.

C. *Fredrik Ohlson*

Sections written: V, VII.

D. *Ratchanon Sitthinuncharoen*

Sections written: III, VIII.

E. *Lucas Stoppa*

Sections written: IV1, IV3.

References

[1] B. Günay B. Sosa H. Venkatesan J. Götz L. Byrne, K. Seidel. Low Mass Human Mission to Mars / Blue Team - Mission Design Report. March 2022.

[2] L. Messmer S. Stenberg W. Josefsson Rudberg G. Dal Toso, J. Salminen. Low Mass Human Mission to Mars / Blue Team - Logistics Report. March 2022.

[3] O. Malm T. Holmboe S. Weißenböck L. Wullschleger C. Segretin, K. Wen. Low Mass Human Mission to Mars / Blue Team - Transfer Vehicle Report. March 2022.

[4] L. Murphy M. Chillet W. Widyatmoko K. Persson, K. Nordström. Low Mass Human Mission to Mars / Blue Team - Human Aspects Report. March 2022.

[5] N. Kusolphisarnsut M. Moore N. Moriya I. Taxis M. Dahlman, R. Franzè. Low Mass Human Mission to Mars / Blue Team - Mars Operations Report. March 2022.

[6] L. Akabas. Fifa looks to double down on its world cup profit machine: Data viz. https://www.sportico.com/leagues/soccer/2021/fifa-world-cup-proposal-revenue-1234643537/, 2021. Accessed February 27, 2022.

[7] International Olympic Committee. How the ioc finances a better world through sport. https://olympics.com/ioc/funding. Accessed February 27, 2022.

[8] C. Morris. 8 iconic billionaires who plan to conquer outer space. https://www.cnbc.com/2016/09/23/8-iconic-billionaires-who-plan-to-conquer-outer-space.html, 2016.

[9] https://www.pythomspace.com/join/. Accessed February 10, 2022.

[10] D. Haldar A. Hellmann M. Boucher, K. Feng. Mount Olympus Mons Ascension Mission, Overall Coordination - Team Red. March 2021.

[11] Unauthored. How much does it cost to train an astronaut? https://space.stackexchange.com/questions/35431/how-much-does-it-cost-to-train-an-astronaut. Accessed March, 2022.

[12] Unauthored. Wikipedia - Falcon 9. https://en.wikipedia.org/wiki/Falcon_9, 2021.

[13] Unauthored. Wikipedia - Falcon Heavy. https://en.wikipedia.org/wiki/Falcon_Heavy, 2021.

[14] T. Grimonprez B. Logiou F. Malmborg, O. Andersson and A. Parks. Mount Olympus Mons Ascension Mission Mars Operations - Team Red. March 2021.

[15] S. Ruhlmann M. Djouadi, A. Gamba and N. Tanguy. Human Aspects and Life Support System Group Report Human Spaceflight - Blue team. March 2021.

[16] I.A. Crawford. Space development: social and political implications. https://www.sciencedirect.com/science/article/abs/pii/0265964695000188, 1995.

[17] Ethan Siegel. Why exploring space and investing in research is non-negotiable. https://www.forbes.com/sites/startswithabang/2017/10/26/even-while-the-world-suffers-investing-in-science-is-non-negotiable/?sh=3a31deaf1647, 2017.

[18] Luke Harding. The space race is back on – but who will win? https://www.theguardian.com/science/2021/jul/16/the-space-race-is-back-on-but-who-will-win, 2021.

[19] I. Toksöz. Nationalism in outer space: How the global trend of pursuing space programs reinforces (new) nationalism(s). https://www.ipsa.org/wc/paper/nationalism-outer-space-how-global-trend-pursuing-space-programs\-reinforces-new.

[20] James a.Vedda. The role of space development in globalization. https://history.nasa.gov/sp4801-chapter10.pdf, 2009.

[21] NASA. International space station. https://www.nasa.gov/mission_pages/station/cooperation/index.html, 2020.

[22] Tim Jackson. Billionaire space race: the ultimate symbol of capitalism's flawed obsession with growth. https://theconversation.com/billionaire-space-race-the-ultimate-symbol-of-capitalisms-flawed\-obsession-with-growth-164511, 2021.

[23] M. Simon. Capitalism made this mess, and this mess will ruin capitalism. https://www.wired.com/story/capitalocene/.

[24] Jim Taylor. The first person on mars 'should be a woman. https://www.bbc.com/news/science-environment-43724105, 2018.

[25] M. J. Robbins. How can our future mars colonies be free of sexism and racism? https://www.theguardian.com/science/the-lay-scientist/2015/may/06/how-can-our-future-mars-colonies-be-free-of-sexism-and-racism, 2021.

[26] Antonio Salmeri. No, mars is not a free planet, no matter what spacex says. https://spacenews.com/op-ed-no-mars-is-not-a-free-planet-no-matter-what-spacex-says/, 2020.

[27] Office for Outer Space Affairs United Nations. Treaty on principles governing the activities of states in the exploration and use of outer space, including the moon and other celestial bodies. https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html, 2020.

[28] Nicholas Dirks. The ethics of sending humans to mars. https://www.scientificamerican.com/article/the-ethics-of-sending-humans-to-mars/, 2021.

[29] Nicholas Dirks. Space shuttle challenger disaster. https://en.wikipedia.org/wiki/Space_Shuttle_Challenger_disaster, 2021.

[30] Morgan McFall-Johnsen. If jeff bezos' rocket fails during launch, an emergency system should jettison him to safety. https://www.businessinsider.com/blue-origin-rocket-emergency-escape-system-jeff-bezos-2021-7?r=US&IR=T, 2021.

[31] United Nations Office of Outer Space Affairs. Agreement on the rescue of astronauts, the return of astronauts and the return of objects launched into outer space. https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/rescueagreement.html, December 19, 1967. Accessed March, 2022.

[32] Unauthored. Space debris mitigation guidelines of the committee on the peaceful uses of outer space. https://www.unoosa.org/pdf/publications/st_space_49E.pdf. Accessed March, 2022.

[33] D. Oberhaus. To boldly go where no body has gone before. https://slate.com/technology/2015/04/death-in-space-the-ethics-of-dealing-with-astronauts-bodies.html. Accessed March, 2022.

[34] K. Dickerson. Here's what nasa plans to do if an astronaut dies in space. https://www.businessinsider.com/what-if-someone-dies-in-space-2015-4?r=US&IR=T. Accessed March, 2022.

[35] The White House. In event of a moon disaster. National Archives, https://www.archives.gov/presidential-libraries/events/centennials/nixon/exhibit/nixon-online-exhibit-disaster.html?_ga=2.173520805.783401072.1614178676-1823908705.1614178676. Accessed March, 2022.