Hugin & Munin
Overall Coordination

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***Abstract*—Mars exploration has become the next big goal of space exploration for the foreseeable future. This study presents a potential first mission to the Martian Surface, staring in 2026. The mission is developed so it would be crewed by Tom and Tina Sjörgen and financed and constructed by PythomSpace. As part of a larger group that developed a complete concept for the mission, this report presents the work of the Team Red's Coordination group. The role of the Coordination group included the facilitation of collaboration between the groups, and the the study of financial. political and societal aspects of the mission. Additionally, an overview of the entire mission is hereby presented.**

Fig. 1. **Mission Logo - Project Hugin & Munin**

Nomenclature

The list below describes several abbreviations and symbols that will be later used.

LEO	Low Earth Orbit
LMO	Low Mars Orbit
TV	Transfer Vehicle
MADV	Mars Ascend and Descend Vehicle
T & T	Tom and Tina

I. Introduction

A. Project Background

Ever since humanity has reached the capability of space travel, Mars, or so called "The Red Planet", has always been beyond the reach for decades. Main limiting factors such as scientific and technological constraints; or lesser ones like the lack of feasible goals, budget finding method, and even the ever-changing societal and political landscape of the world have made human-based expedition missions to Mars practically impossible for the last few decades. Like the name of the mission: Project Hugin & Munin, Tom and Tina Sjörgren, two world famous mountaineers and founders of Pythomspace, will symbolize the two knowledge-seeking ravens of the Norse god, Odin, by embarking on a 20-day expedition on Mars with main objectives to explore the surface of the planet and to serve as humanity's milestone of being the first human expedition on Mars.

B. Mission Overview

The mission that was developed plans for start in .... . In the first phase, the Transfer Vehicle that will take TT to Mars will be assembled in LEO, using primarily the KANG launcher. After the assembly is completed. a series of launches will ensue that will provide the fuel to the Transfer Vehicle. These will utilize Falcon Heavy to bring the fuel to LEO. Lastly, After approximately two and a half years, and with the TV ready, the two astronauts will launch into Orbit atop a commercial launchers Human Rated System. After Transferring to the TV, they will begin their almost thousand day round trip to Mars. After 308 days, they will enter LMO. In total, they will need to spend around and on Mars a total of 338 days. Of them, 20 days will be spent on the martian surface, where TT will partake in survey, EVA operations on the surface, will deploy various experiments, and will collect regolith to return to earth. To Descent, survive and depart the red planet. the two MADV will be used. One of them will drop materials to the surface in advance and act as a redundant system for ascent in case the main one fails. The second MADV will bring TT down, and will also act as a base. After the completion of their operations on the surface, TT will need to wait in orbit for their next return window. On August of 2028 they ll begin their return to Earth, which will have a duration of 342 days. Upon Return to LEO, T&T will descent to Earth using a commercially available Human Rated system, while the TV will remain in orbit to be sold, leased or re-purposed for future missions. Figure 2 shows the planned transfers during phases of the missions, along with corresponding dates.

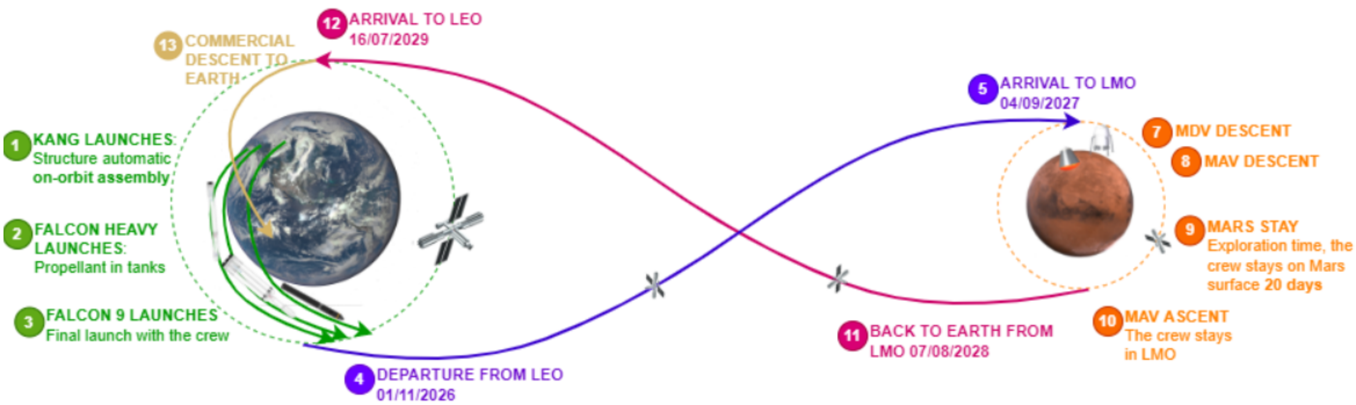

Fig. 2. **Overview and timeline of the mission**

C. Risk Analysis

There has been a lot of failure and incident in the history of spaceflight. Every failure causes a disregard from the public opinion to spaceflight. Failure also causes casualties and a delay in mission. That's why it is important to reduce the risk of these events. [1] Around 83 failures out of 2000 launches had happened. Risk is combined with a lot of others factors to be taken into account when the mission is designed. You have to look for a level of risk acceptable without increasing the cost and the schedule too much and keep all the performance we want so the mission is still feasible. What is important is to respect theses four principles.

- Cost at constant risk, performance must be reduced
- Risk at constant cost performance must be reduced
- Cost at constant performance higher risks must be accepted
- Risk at constant performance higher costs must be accepted

The causes for the majority of failure nowadays are environment, Parts, Workmanship and Design. To increase the reliability of the mission, a lot of tests are done. With the testing is possible to reduce drastically the risk of Class 1 failure. There is still more risk in the first flights than after some real flights done. The accordance between the complexity of the mission and its cost and schedule is also very important. The more complex a mission is more money and more time it requires. In the case, the funding and schedule are not properly sized, the risk of failure increases. Two fault tolerant system should be put in place for every critical function.

D. Legal Aspects

Since the beginning of the space conquest, only powerful countries were able to launch rockets and to send people to outer space. First, because of regulations but also due to the financial aspect of such launch and mission. Now that the regulations on what can be brought from outer space and the fact that some people can afford to do space tourism. Companies funded by billionaires have started to launch rockets to outer space. They also start to have contract with the spatial state agency. As today company such as Space X are valuated more than the annual budget of the NASA.[2]

II. Methodology

A. Internal Organization

The Red Team was separated in six (6) different groups. These groups had different goals and cooperated to generate a holistic preliminary mission concept. These teams and their roles were:

1) Mission Design: The responsibilities of the Mission Design team lies mainly with the trajectory design of the vehicles during the mission which includes the paths; the departure, the interplanetary transfer and the capture method; and delta v. All of which were ultimately translated to the resulting time span of the mission. Lastly, the optimal launch date was narrowed down and selected (by solving Lambert's problem) alongside the final trajectory path [3].

2) Transfer Vehicles: The focus of the Transfer Vehicles is in developing the vehicles suitable for the transfer operation from Earth's to Mars' orbit and then to and from the martian surface. Hence, the vehicles designed would need to be able to carry the necessary payload and propellant for the mission, while also being able to incorporate equipment such as life support systems, research and exploration equipment into the modules. More in-depth aspects of the vehicles themselves e.g., electrical system, propellant selection and system, were presented. Lastly, the conceptual designs of Mars descent vehicle and ascent vehicle were also proposed alongside the desired descent and ascent trajectories [4].

3) Logistics: In addition to planning the overall timeline of the mission, scheduling, and conducting research and developing for the on-orbit initial vehicle assembly sequence in Low Earth Orbit, the Logistics team's main tasks also consist of matters regarding communication – to provide T&T with a suitable dedicated communication technology and architecture system which minimizes the possibility of a communication blackout [5].

4) Human Aspects: Like the name suggests, the Human Aspects team is responsible for all matters related to humans in the mission, specifically the effects of the space environment to the human body, and how to design the life support system (LSS) and other human-rated parts of the mission in accordance with that knowledge. Such topics include radiation control, consumables and air supply, aspects circulating psychological and physical health needs, hygiene, and training required for the mission [6].

5) Mars Operation: The Mars Operation team is in charge of the portion of the mission conducted on the Red Planet which includes all aspects of the Mars base, operations which will be carried out by the Pythomspace crew, and exploration equipment such as spacesuits, hand tools, and reconnaissance drones. Thorough atmospheric and environmental research of both the planet and the selected landing site was also done by the team in order to complete the design on the previously aforementioned topics [7].

6) Coordination team: The Coordination Team was responsible for establishing the working framework and ensuring collaboration between the teams. Additionally, the coordination team was responsible for the financial budget of the , the risk assessment and the political, societal, and legal aspects.

B. Organization and Collaboration

The Coordination Team's goal was to establish a common truth for all the cooperating teams and to create an environment where concurrent development could occur. Firstly, communication and collaboration tools were established in the form of Google Drive Folders with prescribed file system structures, and Slack channels per team. Afterwards, the teams were encouraged to decide upon their internal structure and to appoint one "team lead" which would be the same person for the entirety of the course. This person had the role of being the main point of interaction for each team with the other teams. This way we were able to control the flow of information as it went only through one person per team. To manage information as technical details and generic and internal requirements, files were set-up in the online platforms that allowed for the communication of Assumptions, Goals and Requirements as well as to store and request values such as mass, bandwidth, or power for different systems. To avoid "blank-page syndrome" the team members were motivated to use "Scientific Wild-Ass Guesses" so that we could start from a certain level of rough numbers and hone them in gradually. These were all established with the various working groups. To establish a frame upon which everyone knew, in rough terms, what was going on in other teams, and to boost the ability to co-decide and co-design the missions, meetings were planned for each week. In those meetings, which lasted between 30 and 60 minutes, every team showed what their goals had been so far, what they accomplished and what are they planning to do. Lastly, they also mentioned the blockers they are currently facing and who they would need help or data from. This process generated a feeling of involvement for all members involved and allowed our team to foresee potential conflicts or to gather information in advance of a potential blocker. Also, material relative to each group was distributed accordingly to help inspire the first steps of the groups.

1) Assumptions and Requirements Generation: To facilitate this initial phase, the coordination team organized brainstorming sessions were the entire group got to question and describe the mission objectives. This way, a large image of the main questions at hand was formulated.

To better understand PythomSpace's aims for the mission, the coordination team collected and compiled various questions for an interview with T&T. Some of the questions were:

- What do you consider as a minimal mission?
- Do you aim to create Human Rated Launchers?
- What are the objectives (scientifically and for Pythom Space company in general) for this mission, and what's the future of it (goal is to have a full time base, or is it a "one time thing")?
- What habitable volume would you expect if you were going to be trapped inside it for up to 250 days? Do you believe that the existence of a window would affect how much space you would need?

Using the information that was collected both by the mission description of the course and by the interview with T&T, the Coordination team, collected all potential assumptions and requirements. These were later discussed between the team leads, who were directed to critique them internally in their teams and to rate them on the feasibility of working with those Assumptions and requirements during the workshop. The feedback that the teams generated was collected by the coordination team and was consolidated into one report for the assumptions. This way different parts were disregarded as they were deemed to complex for the scope of the concept, and some helped in the formulation of design drivers. Following this process, a series of assumptions, requirements and goals was generated that were affecting all subgroups. The teams were encouraged to disregard any other information point the had and to use these as the common truth for the entire design process.

2) Trade-offs: Based on the goals, requirements, and assumptions that we generated, we developed a set of criteria that were used by the teams for their trade-offs analyses. These were also assigned a weight, to complete weighted trade-offs tables shown in Table I. As for the main assumptions and requirements, they are presented in Table II and Table III

After this groundwork was set, the role of the coordination team transitioned into a supportive one, as the team made sure everyone had what they needed in terms of information. Complementary to that, the Coordination team checked in the separation of work that most aspects of the concept would be covered by the teams and that any potential blockers were resolved. Lastly, in any crucial decision-making process, team meetings that included members by the teams responsible for aspects of the mission were coordinated. Lastly, to facilitate

TABLE I
TABLE OF THE SET GOALS AND THEIR WEIGHT

Number	Goal	Weight
G-1	Low risk (hard limit on 3%)	8
G-2	High TRL (higher than 6)	8
G-3	Minimise Mass	10
G-4	Minimise Cost	7
G-5	Minimise Waste (in orbit)	2
G-6	Minimise organic waste (on martian surface)	10
G-7	Minimise Mission Duration	4

TABLE II
TABLE OF THE MISSION ASSUMPTIONS

SYS-01	Kang has 3t Capacity to LEO
SYS-02	Kang can launch for 1000$ / kg
SYS-03	Kang Launcher will be ready in 2024
SYS-04	Kang launcher will be preferred.
SYS-05	Kang Launcher will use Green Fuel.
SYS-06	The mission will consist of a crew of two.
SYS-07	The expected success rate of the mission is 75%

TABLE III
TABLE OF THE MISSION REQUIREMENTS

COOR-001	The Mission start shall be as soon as reasonably possible.
COOR-002	Number and cost of launches shall be minimized.
COOR-003	The mission shall be less than 1000 days.
COOR-004	Days spent around mars and on martian surface shall be minimized.
COOR-005	Material left behind shall be minimized. Organic material shall be minimized. (Planetary protection compliance)
COOR-006	The station shall NOT rotate
COOR-007	The amount and cost of vehicles will be minimized.
COOR-008	The total volume of the station and its mass shall be minimum.
COOR-009	The station shall NOT have telescopic habitable volumes
COOR-010	The total cost of the mission shall be kept to a minimum.
COOR-011	The mission shall NOT accommodate cave exploration missions.
COOR-012	The mission shall accommodate sample returns.
COOR-013	The crew shall have extended astronaut training, including medical training in microgravity environment and EVA training.
COOR-014	The ground control team shall be comprised by a diverse and multi discipline group.
COOR-015	The crew shall have the capacity and know-how to address problems independently of ground control. Especially for the first two hours of any incident, the crew shall be trained to be completely competent.
COOR-016	Vehicle parts shall be reused throughout the mission where possible.
COOR-017	The chance of crew death shall remain lower than 3%
COOR-018	The crew shall have the capacity to fix any issues that arise in the exterior of the spacecraft.

the teams and the coordination team's work, an online spreadsheet was created that was used to distribute tasks and subtasks within the group.

The coordination team also contributed in auxiliary tasks like generating a mission name, a mission logo, hosting and moderating online meetings and generating the templates for presentations.

C. Risk Analysis

In order to properly design the mission in terms of risk one has to first of all define the minimum set of functions. Then, you make it work and make it safe before making it reliable. There is some principles that has to be taken in account :

- Simple is better than complex.
- Passive is better than active.
- Active two state devices are better than continually acting devices.
- Passive devices are better when subjected to well understood load than to unknown or uncertain loads.
- Continually acting devices that move over a range of position are better than continually rotating device.
- low rotational speed is better than high.
- When safety enhancement of a simple system is required, robustness is preferred over diversity, and diversity is preferred over duplicative redundancy.
- make sure redundancy doesn't have a correlated failures factors

There is also different type of risk :

- Safety
- Mission Success
- Development

Safety is the most critical type of risk, indeed casualties are not wanted. This type of risk always cause a risk in the mission success, that's why it has to be minimized. A successful mission start with making everyone coming back safe.

Development risk and Mission success are linked. If you try to minimize the development risk by testing less you are increasing the risk that the mission doesn't succeed.

So the balance between development risk and mission success risk is important. If the development risk is tried to be reduced too much then it will need more money and more time. Otherwise, if not enough test are done the risk concerning the Mission success will be too high.

D. Financial Aspects

To understand how this mission can be funded, other missions within the same scope were analysed. Then a inventory of all the different sources of money that can be used was done.[8]

E. Political Aspects

For the research of human spaceflight in aspects of political and societal, a bibliographic study has been performed. The main materials and resources have been gathered from the space agencies, NASA and ESA, the research discovery platform ScienceDirect and Nature.

III. RESULTS & DISCUSSION

A. Cost Analysis

The estimation of the cost for a space mission is a key factor for its success. Indeed, a solid financial business plan have to be based on a cost estimation as accurate as possible. In order to do so and based on the NASA Cost Estimation Handbook [9] the Figure 3 presents the three different steps required.

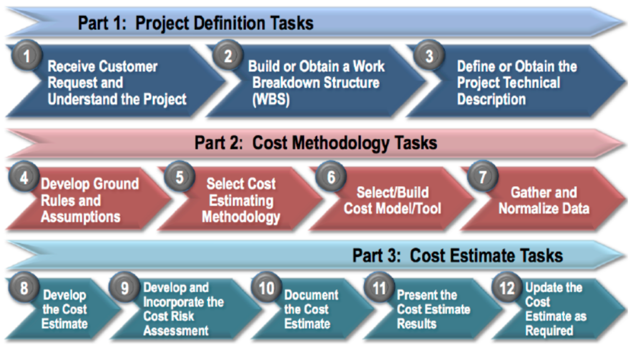

Fig. 3. **Three cost steps**

The goal of the project is to go to Mars, stay 20 days on the surface and then come back. As mentioned in the first studies made by the Mission Design team [3], the overall mission will last roughly 1000 Days. Two crew members, Tina and Tom, will take part to this mission and their spacecraft will weight around 600 Tonnes with propellant according to the Transfer Vehicle Team [4]. In order to estimate more accurately the cost of the overall mission, the latter has been separated into four main parts : ground system, launch system, spacecraft system & development, Mission operations.

The ground station will include the work facilities, rental of premises, basic needs such as propellant or electricity, basic communication needs and working tools. Based on the ESA financial report of Kourou space centre of 2003 [10], the cost of the ground station is estimated to be 250 000 $ a year. The mission will last 3 years so the total cost is around 750 000 $.

Except the Kang launcher that is developed currently by Pythom, the launch system will only use commercial launchers [5]. The Logistic Team planed to use the launchers presented in Table IV .

TABLE IV
TYPE OF LAUNCHER, THERE NUMBER AND COST [11][12]

Launcher	Number	Launch price [$/$Kg$]
Kang	4	1 000 $
Falcon Heavy	10	2 150 $
Falcon 9 - cargo	1	2 720 $
Falcon 9 - crew dragon	1	55 $M/pers

The launch price for the overall mission is then estimated to be around 1.084 $B which is really low compared to the missions that occurred before before the two thousandths. This is explained by the increased technological development and the private companies such as space-X or Blue Origin new in the aerospace sector and therefore very competitive.

The spacecraft system & development is the main and major cost of the overall mission. In order to estimate its price, a parametric analysis of previous spacecraft development cost has been done. To do so, a data base has been build regrouping the weight and the development cost of different spacecraft that has been build so fare [13]. Because 1$ in the past has not necessarily the same value as 1$ now because of the inflation, all prices has been changed to adapt to the current dollar value. A trend line has then been draw to perform a parametric analysis. However, the R-squared value measuring the trend line reliability is quite low (0.283) showing that prices for spacecraft are scattered. Thus, the estimate found will not be very accurate but will give a first average estimation of the cost. Results of the analysis are shown in Figure 4.

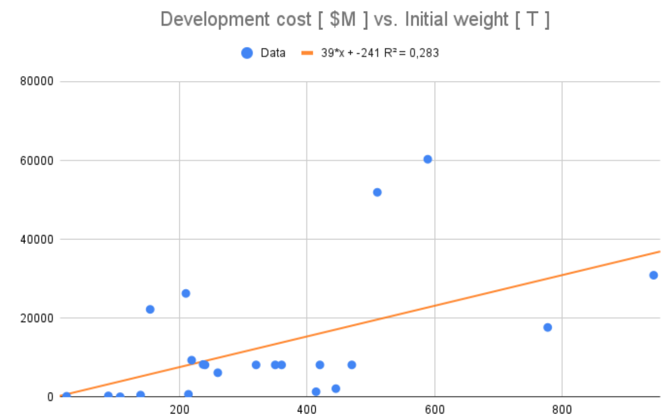

Fig. 4. **Parametric analysis of the development cost**

Applying the trend line equation for the estimated weight of the aircraft (600 Tonnes wet), we obtain a cost around 56.8 $B. This cost can appears to be a lot but compared to the International Space Station which cost is roughly 150 $B for a weight of 400 Tonnes [14], the estimated cost is quite reasonable. All the more that the spacecraft have to go to Mars and come back.

The transfer vehicle team has estimated the requirement of two Mars Landing module [4], one that will weight 4.19 Tonnes and the other one 4.75 Tonnes. To estimate the cost of each one, an analogy has been done with the Moon Landing module [15] - Apollo 11 - and a cost of respectively 6.4 $B and 7.3 $B have been found.

Finally, the last cost to estimate is the Mars operation cost. It include the water system, oxygen system, EVA suit, drone, exercise equipment, radiation shield, food equipment and communication system.

- **Water system :** Based on the water system estimation made by the NASA in 1970 [16] and with the inflation, a cost of 30$M will be required
- **Oxygen system :** Again, based on the NASA estimation [17] and taken the inflation into account a 28.5$M cost is evaluated
- **Space suit :** According to NASA the purchase of one of its space suit is around 10$M [18]. But other actors like space-X or MIT might drop the price for 5$M
- **Drone :** Mars Operation team estimated that they will required a drone to explore. Based on Ingenuity drone

developed by NASA, its cost is evaluated around 2.4$M (development not included) [19]

- **Exercise equipment :** The exercise equipment cost is estimated to be roughly 0.5$M
- **Radiation shield :** Based on previous radiation shield project, the cost is estimated around 2$M
- **Food equipment :** It has been estimated that the cost is 40$/Day/person so a total of 0.08$M for the all mission
- **Communication system :** The logistic team estimated that a satellite is required for the communication during the mission. A cost of 260$M of satellite and 60$M of launch has been found by them [5]. So a total of 320$M for the communication system

To make it simple, the overall cost of the mission are detailed in the Table V bellow. The overall mission is estimated to cost around 72$B in total. This is a an early estimation, it allows to compare the mission with the ISS costing 150$B and the upcoming Artemis program at 90$B. As the project progresses, it will be necessary, as indicated by the NASA procedure, to specify this total revision cost.

TABLE V
DETAILS OF THE OVERALL COST DISTRIBUTION

Name	**Section**	**Price $M**
Ground station	Ground system	0.261
Communication	Ground system	0.489
Kang launch	Launch system	12
Falcon heavy launch	Launch system	900
Falcon 9 - cargo launch	Launch system	62
Falcon 9 - crew launch	Launch system	110
Mars descent&ascent vehicle	Spacecraft development	6425
Mars descent vehicle	Spacecraft development	7283
Main spacecraft - TV	Spacecraft development	56756
Water system	Mission operations	30
Oxygen system	Mission operations	28.5
EVA Suit	Mission operations	5
Drone	Mission operations	2.4
Exercise equipment	Mission operations	0.5
Radiation shield	Mission operations	2
Food equipment	Mission operations	0.08
Communication system	Mission operations	320
TOTAL		**71 937**

B. Risk Analysis

To have a proper view of the different risk the mission is facing, it is useful to proceed by analysing every subsystem. The results have been put in the table VI.

The objective is to have no High risk event which are the one in red in the table to avoid this mitigation strategy must be put in place. For instance, in the case of the assembly the failure rate is 0.5 if we don't do any ground testing before. If we do ground testing it becomes 0.15 which is more acceptable.

Failure of communication is not important since there is only a support team on Earth and not an operation team. All the other risks in the table were evaluate with their mitigation

TABLE VI
RISK TABLE

probability → critically ↓	Low		moderate		high
Low			drone breaks coms failure		
		Outside communication failure			
Moderate	Solar storm Failure of a supply rocket	Critical module damaged during descent Life support system failure Habitat leakage	Suit leakage outside		
High	Fire in Mars habitat Severe Mars sandstorm Failure of the crew rocket	Failure of as-sembly		Inability to fund the project	

action. Environmental risk such as radiation don't appear there since there are not a risk that can be mitigate,it just the reason space suit are needed. The risk is describe for the equipment the team is engineering. For example the Sandstorm risk is mitigated by putting batteries on space suit and space habitat. Every risk is handle by using the mitigation techniques described before. The only high risk which can't be mitigated at the moment is the one about the budget since the objectives of the mission are still pretty unclear even after the meeting with T&T. This is a huge setback for investors because they don't know on what they are investing and if they can get any return on investment. The mitigation strategy for that would be to precise the goal of the mission more than just "going on Mars". Even if it's the highest risk at the beginning it will only impact on the schedule by possibly delaying the project. And if there is really no investors found it could mean the cancellation of the project.

C. Legal Aspect

Since the mission will be based in the United States, it is important to comply to all US regulations. Moreover, in space not only US regulations apply but a lot of multilateral agreements that even private companies have to follow. Private spaceflight became legal in 2004 but no license was accorded to any company. Before every launch, private companies, have to ask for the authorization from the FAA and NASA. [20]

Fig. 5. NASA Logo

Fig. 6. FAA logo

In 2016 the first clearance for a private flight to the Moon was given by FAA.

The treaties in force in space must be respected. For example the Outer space treaty which was the first multilateral to be signed for space.

In case of too much risk of failure, there is à chance that the FAA will refuse to give any clearance due to the Space Liability Convention whic states that à spacecraft launch from one country is fully under the responsibly of the country of launch in case of any damage in another country. With the Commercial Space Launch Competitiveness Act of 2015 it is possible to plan to use Mars resources for funding the mission since it stated that American citizens can keep anything they brought back from space. For now, there is no precedent of individuals visiting Mars, the outer space treaty only states that you cannot claim sovereignty over a part of any celestial body.[21]

D. *Financial Aspect*

After reviewing all the potential income streams the company can get, the conclusion was that private investors would be needed to fund a big part of the project. However, some funds could be secured by what the project could generate [22] : For instance, the TV can be sold to another firm when it is built and after the property is transferred to the buyer it could lead to gains up to 5000 M $ Cultural income can be at least 200 M $ according to what was generated after the first journey to the Moon. 1kg of Mars soil is worth more than 10 M dollars so it is possible to bring some on the way back. The first company to reach Mars could be evaluated upwards to 25000 M $ according to the worth of other breakthrough company. The funding estimations were highly dependant on the speed the project is done.

E. *Political Aspects*

An investment in human spaceflight for a variety of reasons has always been political. It has been a space race since the Cold War, between the USA and the Soviet Union. The competition intensified as Europe, China, Canada, India, and Japan established their own space agencies. Many countries, space agencies and private space companies worldwide are currently competing and investing to overcome space challenges.

The progress and success in exploration of Mars could be one of the biggest and most important events in the history of mankind. Especially as the social media becomes more powerful and change the way for communications. The status for the country, the company and/or the team behind this success will be inspirational and prestigious worldwide. It would be a significant proof of advanced technologies and abilities. It will commence a new era of human spaceflight.It gives the possibility for interplanetary travels and colonization, where the ultimate goal is self-sufficient human presence.

However, a sustainable space exploration and development is a hard challenge that requires international collaborations. No one nation can pursue a spaceflight program and explore space on its own. Due to the cross-cultural and political differences, it requires a cooperative framework that take into account the differences in political systems, budgets, goals and the cultural values. In attempt to advance a long-term and beneficial human space exploration strategy, the agencies established and participated to International Space Exploration Coordination Group, ISECG[23]. This forum is not compulsory to participate. Its purpose is to share information about their space exploration plans, objectives, and interests. Optimize the possibility and opportunity for collective efforts and enrich individual agency exploration programs. The frameworks are intended to enhance the global coordination and cooperation. It shall consider to potential barriers, planetary protection, contamination to Mars and back to Earth.

Another essential aspect to include is the political system, budget, cultural values etc after the colonization on Mars. This is a very difficult and complex mission that requires extended international collaboration and frameworks in details to achieve progress and success, to stabilize the living conditions and coexistence.

F. *Societal Aspects*

An investment in space exploration programs can associate with a contribution and research in higher technologies for a better future. At the same time, it has many disadvantages. For the advantages, it can deliver social and economic impacts. In a societal point of view, the human spaceflight program and exploration of Mars could increase the knowledge of the planet beyond expectation. The challenges that agencies need to overcome force them to generate new technical innovations that can be economically valuable and benefit public life on Earth. Thus, public support is crucial.

In the aspects of government and private aerospace companies, it's a good chance for promotion that encourages economic expansion, locally and nationally[24]. By transferring innovative products and services to other countries and industries for commercial use. In conjunction with the expansion and economic advantages, it will support and create employment opportunities. For stakeholders, taxpayers, entertainment industry and social media platforms, this could be a new interesting and profitable area for investments. For educational purposes, advances in space exploration inspires and attracts students to science and engineering[25]. This can strongly contribute to the implementation of a long-term exploration program.

Despite the advantages, it needs to consider the risks and circumstances that may affect health, performance, and environment. These could be caused by radiation, space debris and air pollution. These could have an impact on the human health and long-term quality of life for public life on Earth and for space explorations[26]. Space debris increase the risk for collisions with other satellites and rockets in space, but for larger objects or compact structures, they may survive a reenter to the atmosphere, and in an uncontrolled way hit somewhere on Earth. Which could be dangerous for human[27]. Air pollution is another important aspect to consider, especially for normalized space travels. Rocket engines emitting pollutants in higher layers of atmosphere that could be harmful and affect the climate on Earth[28].

IV. Conclusion

A. Collaboration

The tools, techniques and processes that were developed and implemented from the coordination team allowed the entire group to work within a concurrent engineering environment. This was possible through the availability of data variables to all members, the common base of requirements and assumptions and the regular team updates. This proved helpful in generating a complete concept, were each team complemented the work of other teams and were the decisions that were made were well informed by the different disciplines that applied to that decision. Overall, a positive environment that allowed for discussion benefited the project overall and encouraged the participants to actively participate in the project.

B. Feasibility

This work, and that of the entire Red Team during 2022's SD2905 class, showcases how close human kind is to becoming space-borne. Most technologies required to put humans on Mars are already there or are currently under development. As showcased in our report, the most crucial aspect humanity needs to overcome is one of financial and political capital. Financially We were able to understand that the concept that our team develop is comparable with past and future missions that are planed by national agencies.

V. Division of Work

All members participated actively in all tasks with individuals taking responsibility in leading different activities during the workshop and for the report writing.

- *Eungprabhanth Panis*: Lead the writing of the Abstract, Introduction, conclusion, and teams' descriptions for the report. Facilitated the collection of material of from the teams, digital communications and presented in the oral examination.
- *Gaillard Corentin*: Lead the writing of the risk analysis, legal and financial aspects in the report. Facilitated the generation of presentations and the collection of risk related information. Generated templates for final presentation.
- *Heimendinger Gautier*: Lead the writing of the Cost estimation and funding segments of the report. Facilitated the implementation of digital tools and generated and moderated digital databases for the communication of information between the teams. Generated presentation templates for intermediate internal reviews.
- *Lin Xiaoyi*: Lead the writing for the Societal and Political aspects segments in the report. Facilitated the collection of information from the teams, generated and moderated the report in OverLeaf.
- *Magkos Michail*: Lead the writing for Methodology, Organization segments of the report. Acted as "team lead". Facilitated in the communication between groups and in the generation of assumptions, requirements, and goals. Generated trade-offs tables for the teams. Helped in the definition of the mission description.

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