Hitchhiker Space Taxi
Overall Coordination
Team Red

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***Abstract*—The aim of this project was to develop a space-taxi to transport two people from Earth to future space stations and back. The role of Overall Coordination was to manage the team by establishing a framework for the project work and the mission and to develop a business plan. The focus of the business plan was to capitalise on the European Space Agency's (ESA) goal of developing an independent human spaceflight programme. The mission was considered in terms of specific development stages, social and political aspects, logistics and locations, funding, cost, income and environmental aspects. Based on the overall risk assessment, one off-nominal scenario was studied in-depth.**

I. INTRODUCTION

IN 2030, 6 years from now, the International Space Station (ISS) will reach the end of its operational life. In its place, several new stations are planned from both the private sector and governments. This expansion of infrastructure creates the need for a taxi-like space vehicle to transport astronauts between the stations and earth. Thus, our *Hitchhiker* space capsule was developed to meet this demand.

As our name implies, the *Hitchhiker* aims to provide an affordable and reliable transport system, where customers can simply hitch a ride.

II. PROJECT MANAGEMENT AND COORDINATION

The Red team consisted of 18 members split into 4 groups, these being Overall Coordination, Launch & Return, Vehicle Design and Human Aspects. In order for the project to run smoothly, we as a team needed to manage the workload effectively. We, therefore, began the project by identifying relevant topics and inter-dependencies between systems and groups to avoid any overlaps. All groups were informed about each other's progress throughout the project.

In the beginning, we, as Overall Coordination, set up a shared file storage and a communication channel for the whole team. The shared file storage used was *Onedrive* since it is a service all students at Kungliga Tekniska Högskolan (KTH) have access to. The communication channel was a *WhatsApp* community with individual chats for the groups, as well as a chat for communication between groups. The advantages of this was that all work done could be accessed by everyone in the team without needing meetings between groups. This also ensured that information was not overlooked or lost by being stored elsewhere.

There was a total of 8 team meetings. For each meeting, our group prepared a meeting agenda beforehand. An exemplary agenda can be seen in Table I.

TABLE I: Generic Meeting Agenda

Time	Event
10:15-10:20	Presentation of meeting agenda
10:20-10:50	Group presentations of work done before meeting
10:50-11:00	Break
11:00-11:40	Team discussions for major decisions or group discussions
11:40-12:00	Future work until next meeting

The meeting agenda was utilised to ensure that the overall timeline was followed and no time was wasted during the team meetings. The purpose of each group presenting their work done was that everyone knew what the rest of the team worked one, and it also allowed groups to get insights from other specialisations. Since the entire team gathered for these meetings, the focus was on making major decisions in the project and giving an understanding of how the project moved forward. This meant that the individual groups worked outside the planned meetings to prepare. In order to catch any problems and make sure nothing was missed, the groups went through what work they needed to prepare for next time at the end of each meeting.

During all of these meetings, we as Overall Coordination took meeting notes. These were then uploaded to the shared file storage, in case someone missed the meeting or needed a reminder about what was said.

Our group also worked on a preliminary timeline for the project, which was presented on the second meeting and later was made into a Gantt chart which can be seen in the Appendix, Fig. 5. The aim of the team timeline was to ensure that every group should have something to work on at all times and to distribute the work evenly. Decisions that were a relevant or a prerequisite for other groups later work were prioritised.

III. MISSION OBJECTIVE

Our mission objective was to ”provide a safe and profitable transport service for two people from Earth to space stations and back.“ After setting this goal as a team it was one of our first tasks as Overall Coordination to decide who was going to be the main customer of our service.

In 2023 The High-Level Advisory Group (HLAG) published their independent report ”Revolution Space - Europe’s Mission for Space Exploration” and presented it at the 315th session of the ESA Council at their headquarters in Paris. The report pointed out that over the past 30 years, instead of investing in its autonomy in space exploration, Europe chose to pursue partnerships with countries such as the U.S.A and Russia. They conclude that, in light of current global events, ”the cost and consequences of such dependencies have now been brought into sharp focus.”[1] and urge Europe to invest in an independent human space programme. They go on to say that ”For the future, we can foresee for example a European commercial crew capsule with a European astronaut as commander, and astronauts from Latin America, Asia and Africa onboard”[1]. In light of such clear statements we decided to focus on Europe, especially ESA, as our main customer.

In order to support current and future international cooperation we will also offer our services to non-ESA-member states and, on a much smaller scale, to private customers. Naturally we also considered entering the United States of America (USA) market, but we concluded that it was already saturated with companies like SpaceX and Boeing and that a European focus would give us a unique business advantage.

IV. SOCIAL AND POLITICAL ASPECTS

To gain autonomy from the USA and Russia, ESA needs to continue developing its technical capabilities, strengthen its current international partnerships and form new ones. Collaborating with us will help ESA address these challenges.

As will be discussed in detail in the Location and Logistics section of this report, we will launch *Hitchhiker* from Kourou, French Guyana, and land in the Algerian Desert. Kourou is French territory and thus grants ESA autonomous access to space from European soil.

Whilst Algeria is not an official ESA partner nation like Japan or Canada, it has its own space programme and bilateral agreements with several European space agencies. This includes a government cooperation agreement with the French Space Agency CNES and Memorandums of Understanding and Cooperation with the space agencies of the United Kingdom (UK) and Germany (DLR)[2]. Algeria is also a member of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS)[3]. We therefore felt that a strong partnership between ESA and Algeria is a realistic scenario for the future.

Our capsule will be transported from Algeria to Spain and then France, where our refurbishment facility is located. Our Mission Control Centre will be located in Germany. By involving several ESA member states in our operation, we will strengthen international cooperation and ensure continued political and economic interest in the success of our company.

V. LOCATION AND LOGISTICS

A. Launch site

The launch site for the capsule needed to meet certain requirements: that it can launch to all future space stations, is compatible with the launch vehicle, and is politically possible. From these criteria, the launch site Kourou in French Guyana was chosen. Since it is close to the equator, all inclinations can be reached theoretically. Additionally, Kourou is a good choice as we initially plan on using the *Ariane 6* launcher, that also intends to launch from here.

B. Stations

For the space stations in the future, there are 4 upcoming ones that are planned before 2030. These being: *Axiom station*, *Orbital Reef*, *Starlab* and *Haven-1*. None of these orbits are currently released, but we assume they will be similar to the ISS orbit. Especially because *Axiom station* will be assembled at the ISS before it is decommissioned. Launching from Kourou we can reach all of them. This is also important for the landing so that the planned landing site can be reached with minimal fuel cost.

C. Landing

The landing site chosen is the Saharan Desert in Algeria, around 31N 0W. This was chosen for several reasons. Firstly, the capsule was designed in a way to be able to land on land after a decision made by the Vehicle Design team. e to achieve this, the landing site needs to meet the following criteria: open land, no possibility of debris falling on populated areas and politically possible.

The reason it needs large open land is because the capsule landing has a dispersion radius of 25 km in the nominal case and 60 km in off-nominal cases. The landing zone chosen is in the middle of the desert with open space with a radius of over 100 km where there are no human settlements.

D. Recovery and Refurbishment

After landing, both the crew and the capsule need to be recovered. Due to the large dispersion radius we chose to use helicopters to recover it before transporting it back to mainland Europe. Furthermore, by using helicopters, recovery personnel can be on site quickly to assist the crew if needed. The lack of infrastructure also makes this a good choice. After the capsule is transported back to mainland Europe, it will be refurbished in France, where a facility will be set up. France was chosen because the *Ariane 6* launcher is transported from Bordeaux via the ESA *Canopée* ship[4] and as the capsule will be the payload it can be transported at the same time. Another advantage is that the technical competency mostly exists there and it is cheaper to refurbish the capsule there, rather than at the launch site. It is also closer to where the parts can be manufactured if needed.

E. *Mission Control*

The whole operation needs to be managed. There needs to be a presence at the launch site in Kourou, so we will establish a Launch Control Centre there, but the Main Mission Control would ideally be placed in Europe, preferably in a major ESA member state. We decided on Germany, as it is one of the strongest ESA member nations and already home to the Europan Space Operation Centre (ESOC) and the Columbus Mission Control Centre.

VI. BUSINESS PLAN

A. *Development Plan*

The business plan outlines how our company will develop from a mere idea to a full-grown, profitable business. This will occur in specific development stages as described below in Fig. 1:

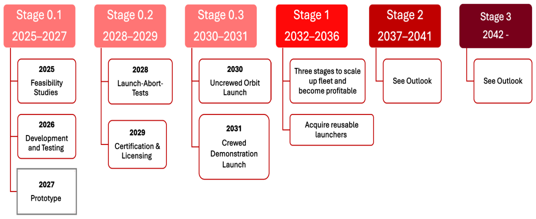

Fig. 1: Development Plan

Stage 0: This stage is the precursor phase to becoming a profitable business and is divided into three substages.

During stage 0.1 we will conduct feasibility studies and then move on to develop prototypes for subsystems. Using an iterative design process we will achieve proof of concept in the form of a working prototype by the end of stage 0.1. This stage lays the groundwork for the subsequent stages by defining the vehicle's design and key technologies.

In stage 0.2 we will conduct launch abort and other safety tests necessary to certify *Hitchhiker* as human rated.

Stage 0.3 will encompass an uncrewed orbital launch and finally a crewed demonstration launch, completing Stage 0 of our development process.

Stage 1: During Stage 1.1 of the development process, which spans from 2032 to 2033, we will operate 2 capsules with launches occurring every 91 days on average.

From 2034 to 2035, during Stage 1.2, we will have increased out fleet size to 4 capsules, launching on average every 33 days. During the final year of stage 1 we will have scaled up our fleet to 6 capsules in operation, with one additional capsule as a backup. We will aim to launch every 10 days on average. A more detailed overview of fleet size and launch frequency can be found in Appendix Fig. 6.

To make this increase in launch frequency possible, we will continually decrease our refurbishment time throughout our development process, as shown in the Appendix Fig. 6. An initial and minimal refurbishment time of 150 days was provided to us by Vehicle Design and references SpaceX's *Crew Dragon* [5]. By 2036 we will have decreased our refurbishment time to 47 days, resulting in a turnover time of 60 days, including the 13 days transport time of the capsule from Algeria back to Kourou.

Stages 2 and 3: Our later stages of development are explained in the Future Aspirations and Outlook section of this report.

B. *Development Costs*

In order to estimate what our development costs would be, we researched similar projects and decided to take *Crew Dragon* by SpaceX as a reference.

In 2014 SpaceX received \$2.6 Billion from NASA specifically to develop *Crew Dragon* and in 2019 Musk noted in a briefing that SpaceX had invested "hundred of millions of dollars more" on top of that[6]. Based on this we estimated a total development cost of $3 Billion. We considered the fact that that SpaceX had the *Cargo Dragon* to build on, which lowered their development costs for *Crew Dragon* significantly. However, since we would also be able to build on existing technology from *Crew Dragon* and other projects like Boeing's *Starliner*, we felt that this would be a realistic estimate for our project as well.

C. Funding

The traditional stages of start-up funding were utilised to predict where funding could be obtained from. In this context, early funding refers to pre-seed, which is the research phase, and seed funding, which should result in proof of concept. This is followed by Series A funding, which is used to support the development process of the product and Series B funding to aid with our business growth.

In order to establish where we could expect funding to come from, it was relevant to investigate where competitors obtained theirs. Space companies like SpaceX, BlueOrigin, and Virgin Galactic were not as relevant to us, as they were built from pre-existing successful businesses. The Exploration Company and their *Nyx* capsule was a better reference for us.

We also focused on finding investors specifically interested in space, especially the European sector by using The NewSpace index's compiled list of space startup funding sources [7]. Through this we could gain access to investors like CASSINI Business Accelerator, which aims 'to put European space initiatives back on the center of the map', a message very in keeping with our own.

Early Funding (2024 - 2027): Pre-seed funding is prior to our specific stages of development, so from 2024 to 2025. As our startup funding, it would likely be used for hiring personnel, market research, acquiring infrastructure, and building a brand [8].

Seed funding would occur during Stage 0.1 of our development, from 2025 to 2027. It would be used for research and development, testing, and feasibility studies. In 2021 *Nyx* received 5.3 Million € in seed money[9].

ESA funding at both pre-seed and seed phases would be unrealistic as we have not yet proven ourselves to be a reliable business.

Series A Funding (2027-2031): After we have demonstrated a working prototype in 2027, we will apply for Series A funding during stages 0.2 and 0.3 of our development process. As we are specifically tailoring our business to meet European needs, we feel confident that we would be able to receive significant funding from ESA, paid out in yearly installments.

Based on the 2023 ESA budget, we identified four sectors relevant to our mission: Human Spaceflight, Microgravity and Exploration, Technology Support, Commercialisation and Space Transportation. Assuming that ESA will follow the recommendation made by the HLAG to drastically increase its investments, we made a projection of ESA's budget development.

The breakdown of ESA funding in Series A and B is displayed in full in Fig. 7 in the Appendix. Table II below shows the total expected funding by year. From this we see our expected funding of 213 Million € during Series A.

TABLE II: Projected ESA Funding

Year	Funding (B€)
2027	0.003
2028	0.015
2029	0.017
2030	0.04
2031	0.138
Subtotal	0.213
2032	0.53
Total	0.743

In 2023, the *Nyx* project obtained Series A funding from several investors, including EQT Ventures and Red River West. The company received a total of 47.3 Million € [10], just from private equity financing. At this point, the company had only existed for 18 months.

Neither mentioned investment company has a specific interest in space, which therefore implied to us that non-space companies may also be interested in investment during this phase.
We again used the NewSpace index to find companies such as EBAN Space, with an interest in Series A funding for European space start ups [7].

Series B Funding (2032): After a successfully crewed demonstration launch in 2031, we expect to receive a one-time payment of 530 Million € from ESA to complete the development of *Hitchhiker* and begin commercial operations.

D. Profit

We intended for a large proportion of our flights to be made for ESA. Given our usage of both their *Canopée* ship, and *Ariane* rocket, the ticket price for ESA would be significantly lower than for other customers. Table III shows the predicted ticket price for different customers in 2032 and later on in development, in 2041.

TABLE III: Price of Seat

Customer	Cost per Seat [Million] 2032	2041
ESA	$70	$38
Individual Country	$80.5	$43
Private Party	$95	$59

As of 2024, SpaceX *Crew Dragon* charges NASA $55 Million per seat, Boeing *Starliner* sees a significantly higher price of $90 Million per astronaut, and the *Soyuz* is similar with $86 Million for each seat [11]. Our capsule is most similar to the *Crew Dragon*, and we expect to use existing technology so a lower price is reasonable for us, however, use of the *Ariane-62* rocket does increase the price as it is 75 Million € for a single launch [12]. Using this data, we estimated an initial ticket cost of $140 Million for each flight, meaning $70 Million for each seat for an ESA mission.
We are also interested in the potential of allowing countries to have individual missions on our capsule. Either for non-ESA members, or ESA members who have personal space aspirations, we feel there is a market here. In 2023, the UK Space Agency bought a *Crew Dragon* mission, paying £200 Million, equal to $255 Million for 4 astronauts, making it $63.75 Million per seat [13]. As $55 Million is the seat price for NASA, this means SpaceX makes around 16% more profit on this mission. We decided on a 15% profit increase compared to an ESA missions for countries individual aspirations, resulting in a price equivalent to $80.5 Million per seat
Finally, we have private party missions, which may be utilised for research or space tourism. To estimate costs, we used the Insipiration4 *Crew Dragon* mission, which lasted 2 days and did not go to a space station [14]. The cost of this mission was 'less than $200 Million' for the 4 astronauts [15]. We expect most of our private party missions to be a length of 6 days and they will always go to a space station. Using this, we estimated at $105 Million per seat, making 50% more profit than an ESA mission.
As we become more and more profitable we will continually decrease our ticket prices. A full breakdown of this is shown in the Appendix, Fig. 8. Eventually, we will be charging ESA only $38 Million per seat down from $70 Million, non-ESA members $43 Million and tickets for private customers will be reduced to $59 Million.
Selling seats is not our only profit potential. We also investigated other marketing opportunities that could be presented for us. Advertising has been used in space before, for example in 2000, Pizza Hut paid $1 Million to feature their logo on a Proton rocket [16]. Earning money by selling ad space could be a good additional income, but may make us be taken less seriously.
Voyager Space has partnered with Hilton to furnish and design the crew lodging of its Starlab [17]. This implies companies interest in advertising their products in space. A similar partnership for us could be looked into, or even a catering deal. Heightening the experience of the astronauts on board whilst

also allowing companies to engage in more subtle advertising would be very mutually beneficial.

E. Cost per Launch

In order to calculate an average cost per flight, we asked the groups to provide us with cost estimates.

Human Aspects:

- Cost of life support systems
- Cost of consumables per flight
- Cost of G-force training

Vehicle Design:

- Cost of Refurbishment

Launch and Return:

- Cost of Launcher
- Cost of Fuel
- Cost of Capsule Transport

Overall Coordination then estimated:

- Cost of Personnel (Appendix Fig. 9)

Based on these figures, we made a budget calculation for our development stages 1 and 2, from 2032 to 2041.

All initial investments, including development costs and purchases like life support systems, transport vehicles, etc... were summed up. After subtracting our projected ESA funding from this the cost was divided by the total number of launches for this time period, this is shown in the Appendix, Fig. 10.

We also considered that costs for refurbishment would decrease over this time and that our launch costs would change on a yearly basis as we transition from the *Ariane-62* to reusable launchers, this projection is displayed in the Appendix Fig. 11.

To estimate the cost for a reusable launcher we referenced SpaceX's *Falcon-9* rocket [18]. As mentioned in the Profit section of this report, we will also continually decrease our ticket prices. Fig. 2 shows the development of cost per launch and income per launch from 2032 to 2041.

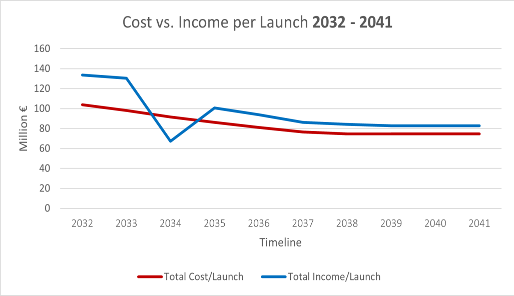

Fig. 2: Cost vs. Income per Launch

A more detailed break-down of this data can be found in Appendix Fig. 12.

We will make a sizeable profit in the first two years, which will compensate for the loss we make in 2034. Even though we will already have a fleet of 4 capsules in 2034, refurbishment time and cost remain comparably high. Consequently, the number of launches that year will be low. To add to this, most of these missions will still launch with the more expensive *Ariane-62*, leading to a temporary loss.

Taking all this into account, we will make an average profit of 12.65 % per launch from 2032 to 2041. To compensate for any unexpected costs, or investments we didn't consider in our calculations, we agreed on a slightly more conservative profit of 10 % per launch. This leaves us with a comfortable buffer of 2.65 %.

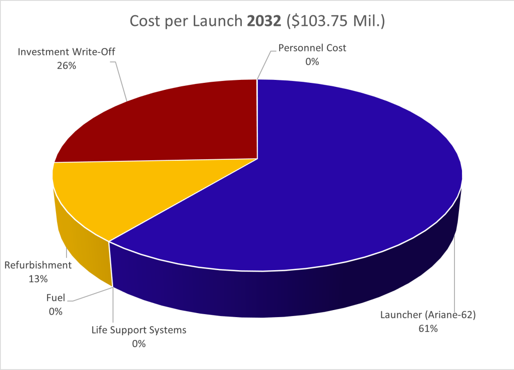

Fig. 3: Cost per Launch 2032

Figure 3 shows the breakdown of costs for a launch with an *Ariane-62* rocket in 2032. This combination of refurbishment cost and launcher is the least profitable for us.

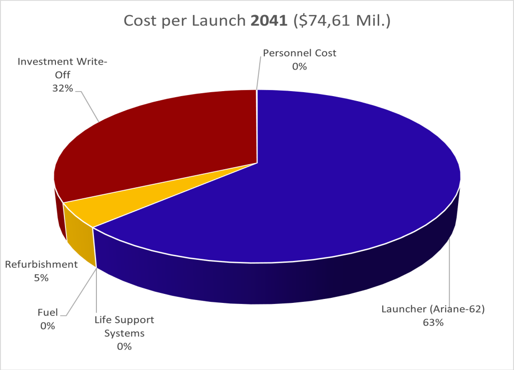

Fig. 4: Cost per Launch 2041

Figure 4 shows the breakdown of costs for a launch with a reusable launcher and minimal refurbishment costs. In both cases the launcher is our main expense, while personnel costs, life support and fuel are negligible in comparison. It is highly feasible that the cost for reusable launchers will also continuously decrease over time. While we did not consider this for our budget calculation, this would eventually lead to an even higher potential profit margin and thus even lower ticket prices.

VII. ENVIRONMENTAL CONSIDERATIONS

As we are focusing on ESA as our main customer and operating out of Europe, we will need to adhere to Europe's environmental regulations, which place a huge focus on sustainability. If we comply with them, that can be a competitive advantage over the industry in the U.S.A.

We are manufacturing all of our components in Europe. This is an advantage because it will keep emissions low due to the shorter transportation routes. The longest transport will be to the launch site, which will be done using the ESA *Canopée* ship, which transports the *Ariane 6* launcher. This ship has sails that allows it to reduce fuel usage by up to 30% [4].

The environmental impact of our fuel choice will be addressed by Launch and Return. At the moment, there will always be some emissions but in the future they can be compensated for. Another benefit is the planned transition to reusable launchers, this reduces the environmental impact whilst also reducing cost.

VIII. FUTURE ASPIRATIONS AND OUTLOOK

During stage 2 (2037 - 2041) of our development process, we will continue to work on our land landing technology, gradually decreasing our target landing radius. Our ultimate goal for development stage 3 (2042 onwards) is to be able to land on a Autonomous Spaceport Drone Ship (ASDS) like the first stage of the *Falcon-9* rocket [19]. Our capsule could land off the coast of Bordeaux and be transported directly to the refurbishment facility without having to be brought from Algeria to mainland Europe first. We realise that this is a technologically complex challenge, but believe it to be a worthwhile and achievable goal for the future of our company.

IX. RISK ASSESSMENT

In order to detect off-nominal cases, an overall risk assessment was performed. A sample of this risk assessment is shown in the Appendix, Fig.13, and the metric for assessing risk can also be found in the Appendix, Fig.14.

As seen in the assessment, risks was sectioned into categories, such as political, health, and safety risks. We assessed both their consequence and frequency of occurrence and then estimated an overall risk value.

From the risk number, we then predicted likely mitigations to these problems. If a case was assessed as having a moderate risk value even after initial mitigations were accounted for, it was deemed an off-nominal case. Such cases required further research to determine how they could be reduced in either frequency or consequence, to give an appropriate, minimal, residual risk value.

Unsurprisingly, all off-nominal cases were found within the safety categorisation. This is due to human life being prioritised over any other risk factors.

X. OFF-NOMINAL CASE

The off nominal case selected is a forced early termination of the mission. This could be caused by several factors with various danger levels. Examples could be rapid depressurisation, fuel or coolant leaks or incoming large Solar Particle Events (SPEs) which endanger the crew.

It is also possible that something goes wrong and the vehicle can't dock, in which case a return might be needed, but it is possible to wait until the normal landing site becomes available.

For the cases where there is not enough time to get to the usual landing site, alternative sites are needed. While there are accords regarding this [20], not all locations are suitable and the company also needs to be able to provide assistance quickly. In such a case, the capsule would perform a splash-down in the ocean.

In order to get the vehicle recovered safely, it is deemed necessary to have rescue operations ready at the coasts of Europe, USA, South America, Australia, Japan. When this occurs it is imperative that the capsule can float until rescue aid arrives. If necessary, the crew can egress from the capsule and local agencies can help according to the Rescue accords adopted by the UN. If the situation is not urgent, the crew can wait until normal ground crew can arrive. By having this capability risks are reduced making it safer and more likely to get customers.

XI. REFLECTION AND EVALUATION

The major limiting factor in the process of this project stemmed from the decision to land on land. This was a decision made by the team with input from Launch & Return and Vehicle Design.

At that time it had already been decided that our business focus would be Europe. The large dispersion radius of the landing combined with the high population density made it impossible land in mainland Europe.

Finding an adequate landing site became an unexpected challenge. We realised too late what major implications our choices of landing mode and business model had for the landing location. In the end a possible landing site was found but this was the largest challenge in the project.

Elsewhere, the distribution of work between the groups was effective and the timeline worked well so that the work was finished in time for the presentation.

XII. WORK DIVISION

A. Lucy Edmond

Wrote about: Introduction, Funding, Profit, Risk Assessment.

B. Viktor Pettersson

Wrote about: Project Management and Coordination, Location and Logistics, Off-nominal case, Environmental considerations.

C. Ishwaaq Mohamuud

Wrote about: Development plan

D. Ewa Marlene Hahn - Example Formatting

Wrote about: Abstract, Mission Objective, Social and Political Aspects, Development Plan, Development Costs, Funding, Cost per Launch, Future Aspirations and Outlook

ACKNOWLEDGMENT

The authors would like to thank Christer Fuglesang, Sören Mohrdieck, and our mentor Nils Pokrupa.

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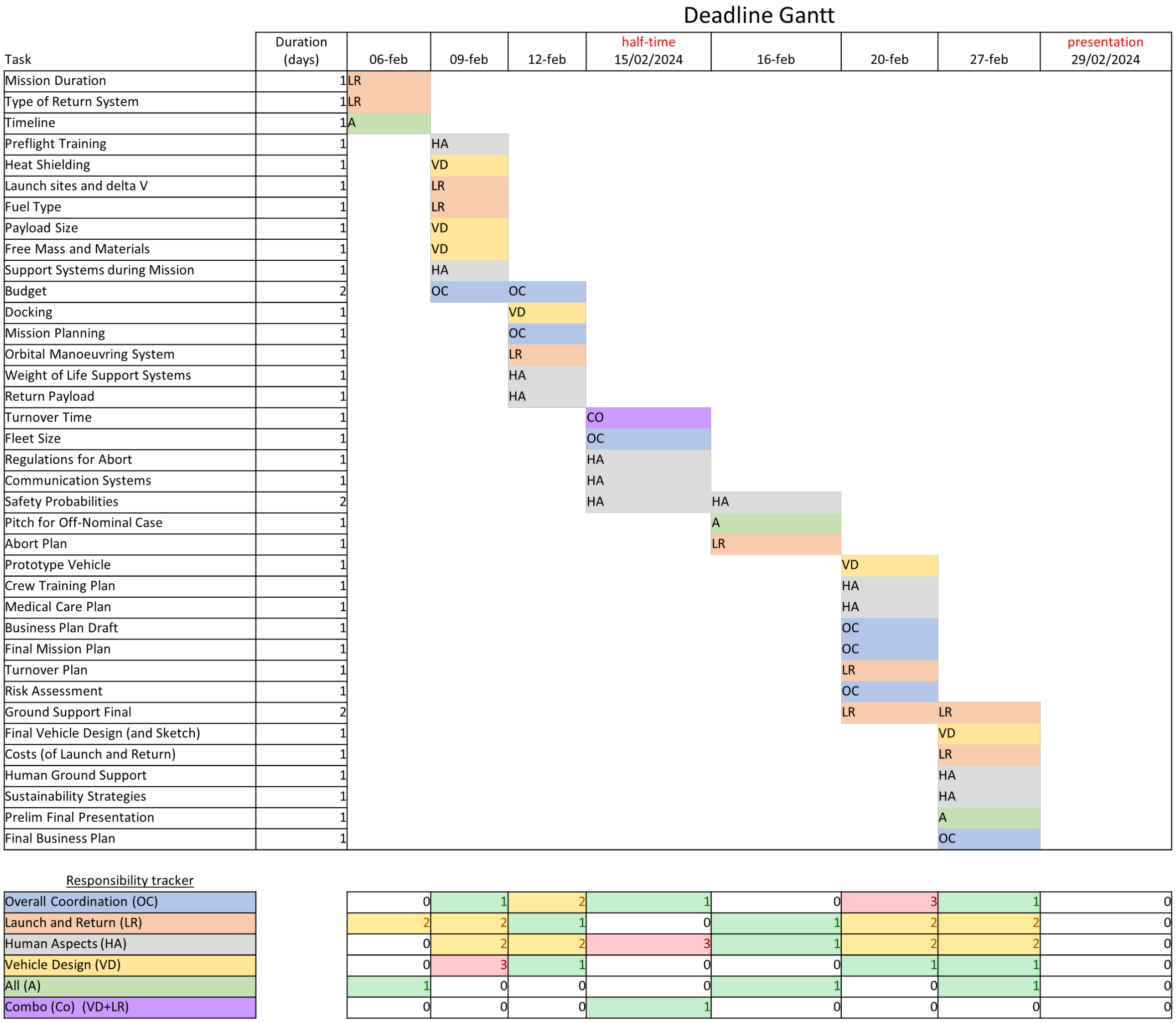
APPENDIX

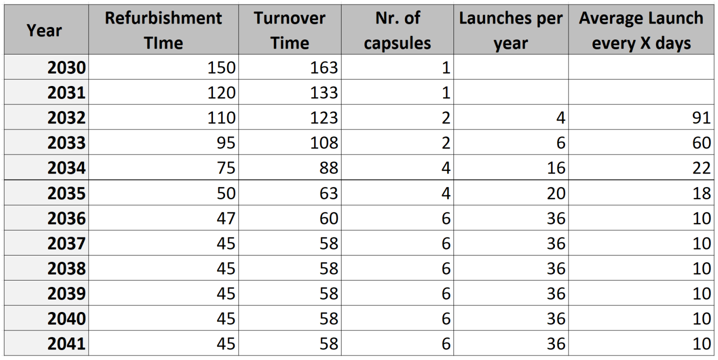


Deadline Gantt

Task	Duration (days)	06-feb	09-feb	12-feb	half-time 15/02/2024	16-feb	20-feb	27-feb	presentation 29/02/2024
Mission Duration	1	LR							
Type of Return System	1	LR							
Timeline	1	A							
Preflight Training	1		HA						
Heat Shielding	1		VD						
Launch sites and delta V	1		LR						
Fuel Type	1		LR						
Payload Size	1		VD						
Free Mass and Materials	1		VD						
Support Systems during Mission	1		HA						
Budget	2		OC	OC					
Docking	1			VD					
Mission Planning	1			OC					
Orbital Manoeuvring System	1			LR					
Weight of Life Support Systems	1			HA					
Return Payload	1			HA					
Turnover Time	1				CO				
Fleet Size	1				OC				
Regulations for Abort	1				HA				
Communication Systems	1				HA				
Safety Probabilities	2				HA	HA			
Pitch for Off-Nominal Case	1					A			
Abort Plan	1					LR			
Prototype Vehicle	1						VD		
Crew Training Plan	1						HA		
Medical Care Plan	1						HA		
Business Plan Draft	1						OC		
Final Mission Plan	1						OC		
Turnover Plan	1						LR		
Risk Assessment	1						OC		
Ground Support Final	2						LR	LR	
Final Vehicle Design (and Sketch)	1							VD	
Costs (of Launch and Return)	1							LR	
Human Ground Support	1							HA	
Sustainability Strategies	1							HA	
Prelim Final Presentation	1							A	
Final Business Plan	1							OC	

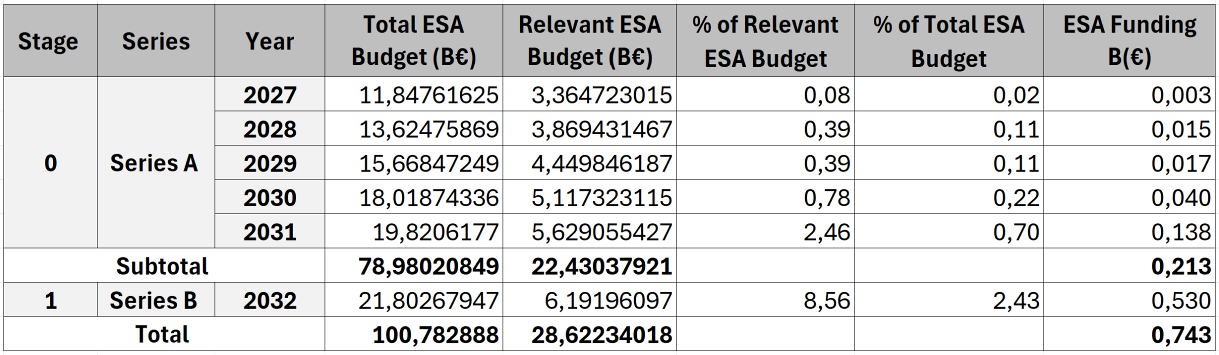
Responsibility tracker									
Overall Coordination (OC)		0	1	2	1	0	3	1	0
Launch and Return (LR)		2	2	1	0	1	2	2	0
Human Aspects (HA)		0	2	2	3	1	2	2	0
Vehicle Design (VD)		0	3	1	0	0	1	1	0
All (A)		1	0	0	0	1	0	1	0
Combo (Co) (VD+LR)		0	0	0	1	0	0	0	0

Fig. 5: Company Gantt Chart



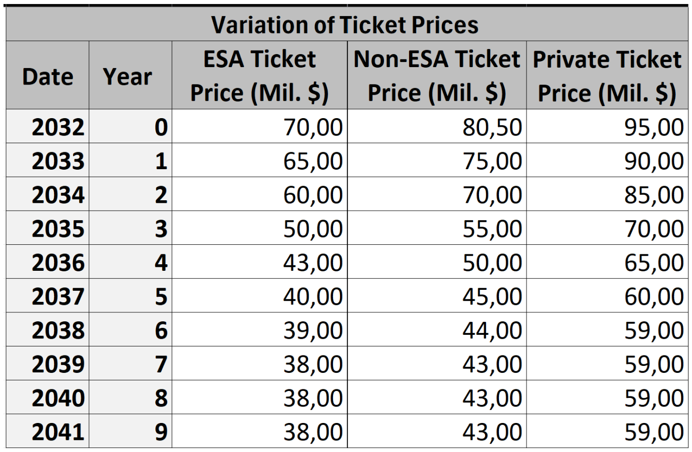
Year	Refurbishment TIme	Turnover Time	Nr. of capsules	Launches per year	Average Launch every X days
2030	150	163	1		
2031	120	133	1		
2032	110	123	2	4	91
2033	95	108	2	6	60
2034	75	88	4	16	22
2035	50	63	4	20	18
2036	47	60	6	36	10
2037	45	58	6	36	10
2038	45	58	6	36	10
2039	45	58	6	36	10
2040	45	58	6	36	10
2041	45	58	6	36	10

Fig. 6: Refurbishment Time



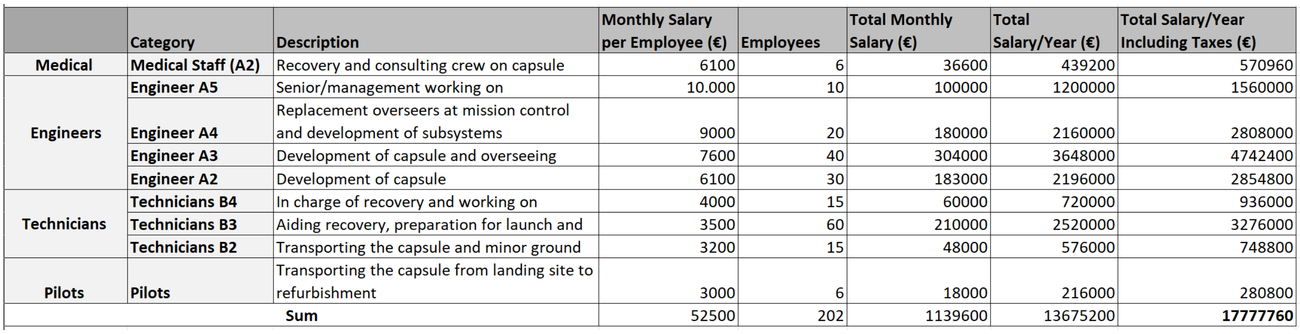
Stage	Series	Year	Total ESA Budget (B€)	Relevant ESA Budget (B€)	% of Relevant ESA Budget	% of Total ESA Budget	ESA Funding B(€)
0	Series A	2027	11,84761625	3,364723015	0,08	0,02	0,003
		2028	13,62475869	3,869431467	0,39	0,11	0,015
		2029	15,66847249	4,449846187	0,39	0,11	0,017
		2030	18,01874336	5,117323115	0,78	0,22	0,040
		2031	19,8206177	5,629055427	2,46	0,70	0,138
Subtotal			**78,98020849**	**22,43037921**			**0,213**
1	Series B	2032	21,80267947	6,19196097	8,56	2,43	0,530
Total			**100,782888**	**28,62234018**			**0,743**

Fig. 7: ESA Funding



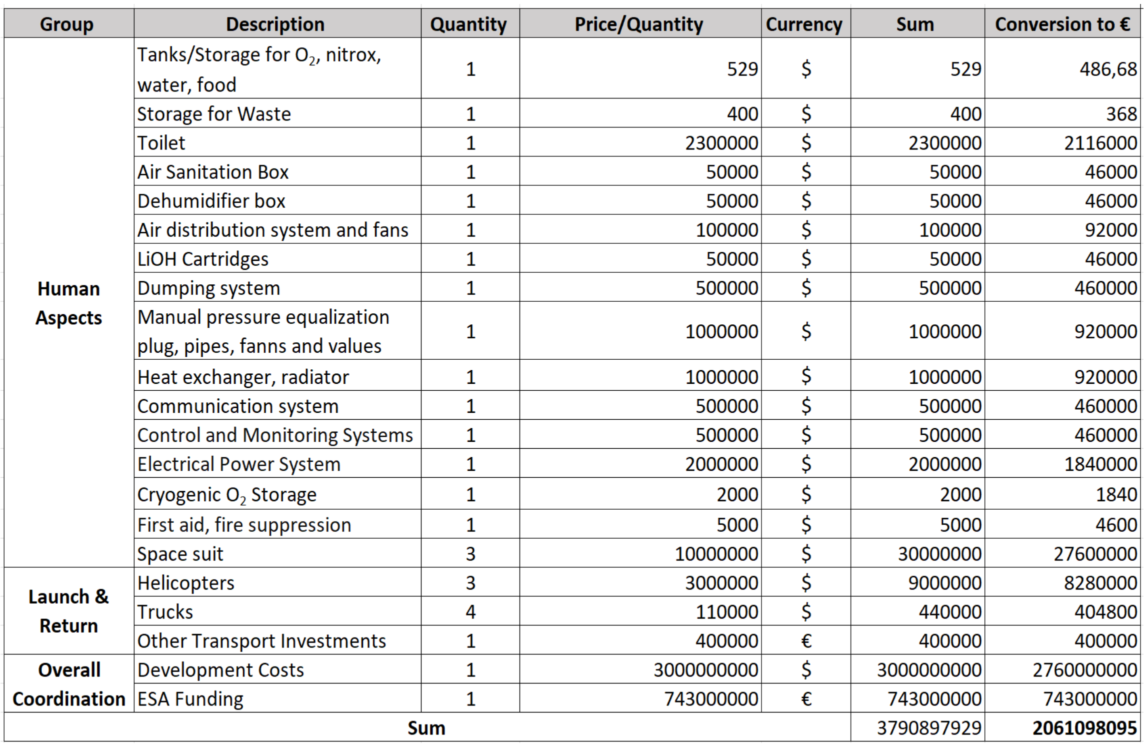
Variation of Ticket Prices				
Date	Year	ESA Ticket Price (Mil. $)	Non-ESA Ticket Price (Mil. $)	Private Ticket Price (Mil. $)
2032	0	70,00	80,50	95,00
2033	1	65,00	75,00	90,00
2034	2	60,00	70,00	85,00
2035	3	50,00	55,00	70,00
2036	4	43,00	50,00	65,00
2037	5	40,00	45,00	60,00
2038	6	39,00	44,00	59,00
2039	7	38,00	43,00	59,00
2040	8	38,00	43,00	59,00
2041	9	38,00	43,00	59,00

Fig. 8: Ticket-Cost



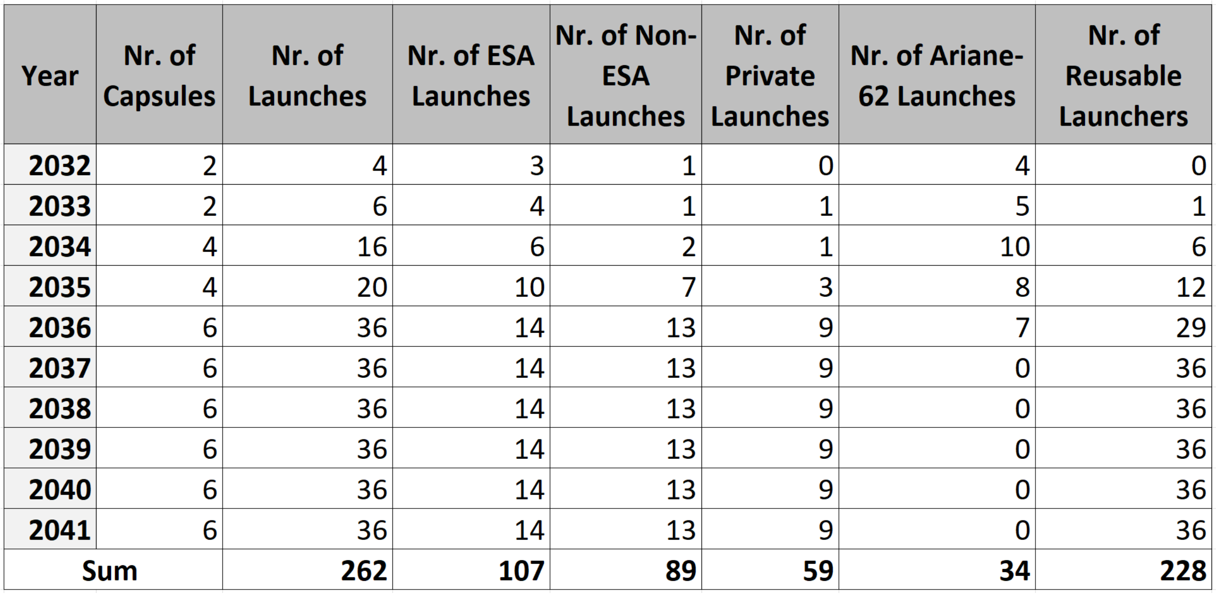
	Category	Description	Monthly Salary per Employee (€)	Employees	Total Monthly Salary (€)	Total Salary/Year (€)	Total Salary/Year Including Taxes (€)
Medical	**Medical Staff (A2)**	Recovery and consulting crew on capsule	6100	6	36600	439200	570960
Engineers	**Engineer A5**	Senior/management working on	10.000	10	100000	1200000	1560000
	Engineer A4	Replacement overseers at mission control and development of subsystems	9000	20	180000	2160000	2808000
	Engineer A3	Development of capsule and overseeing	7600	40	304000	3648000	4742400
	Engineer A2	Development of capsule	6100	30	183000	2196000	2854800
Technicians	**Technicians B4**	In charge of recovery and working on	4000	15	60000	720000	936000
	Technicians B3	Aiding recovery, preparation for launch and	3500	60	210000	2520000	3276000
	Technicians B2	Transporting the capsule and minor ground	3200	15	48000	576000	748800
Pilots	**Pilots**	Transporting the capsule from landing site to refurbishment	3000	6	18000	216000	280800
		Sum	52500	202	1139600	13675200	**17777760**

Fig. 9: Personnel-Cost



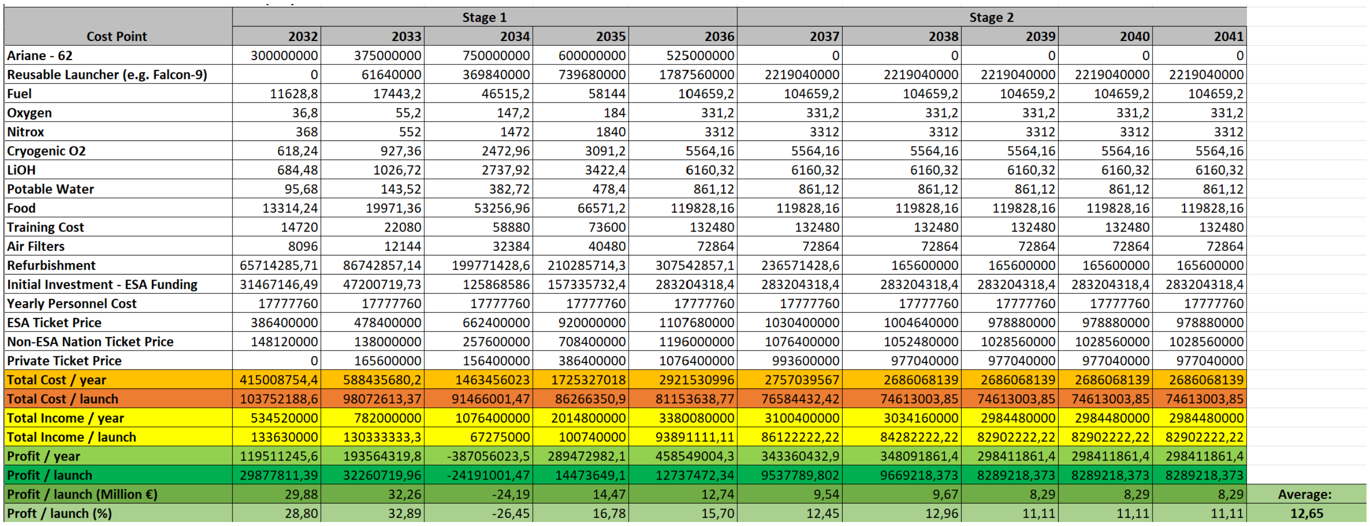
Group	Description	Quantity	Price/Quantity	Currency	Sum	Conversion to €
Human Aspects	Tanks/Storage for O_2, nitrox, water, food	1	529	$	529	486,68
	Storage for Waste	1	400	$	400	368
	Toilet	1	2300000	$	2300000	2116000
	Air Sanitation Box	1	50000	$	50000	46000
	Dehumidifier box	1	50000	$	50000	46000
	Air distribution system and fans	1	100000	$	100000	92000
	LiOH Cartridges	1	50000	$	50000	46000
	Dumping system	1	500000	$	500000	460000
	Manual pressure equalization plug, pipes, fanns and values	1	1000000	$	1000000	920000
	Heat exchanger, radiator	1	1000000	$	1000000	920000
	Communication system	1	500000	$	500000	460000
	Control and Monitoring Systems	1	500000	$	500000	460000
	Electrical Power System	1	2000000	$	2000000	1840000
	Cryogenic O_2 Storage	1	2000	$	2000	1840
	First aid, fire suppression	1	5000	$	5000	4600
	Space suit	3	10000000	$	30000000	27600000
Launch & Return	Helicopters	3	3000000	$	9000000	8280000
	Trucks	4	110000	$	440000	404800
	Other Transport Investments	1	400000	€	400000	400000
Overall Coordination	Development Costs	1	3000000000	$	3000000000	2760000000
	ESA Funding	1	743000000	€	743000000	743000000
Sum					3790897929	**2061098095**

Fig. 10: Initial Investments



Year	Nr. of Capsules	Nr. of Launches	Nr. of ESA Launches	Nr. of Non-ESA Launches	Nr. of Private Launches	Nr. of Ariane-62 Launches	Nr. of Reusable Launchers
2032	2	4	3	1	0	4	0
2033	2	6	4	1	1	5	1
2034	4	16	6	2	1	10	6
2035	4	20	10	7	3	8	12
2036	6	36	14	13	9	7	29
2037	6	36	14	13	9	0	36
2038	6	36	14	13	9	0	36
2039	6	36	14	13	9	0	36
2040	6	36	14	13	9	0	36
2041	6	36	14	13	9	0	36
Sum		**262**	**107**	**89**	**59**	**34**	**228**

Fig. 11: Launches

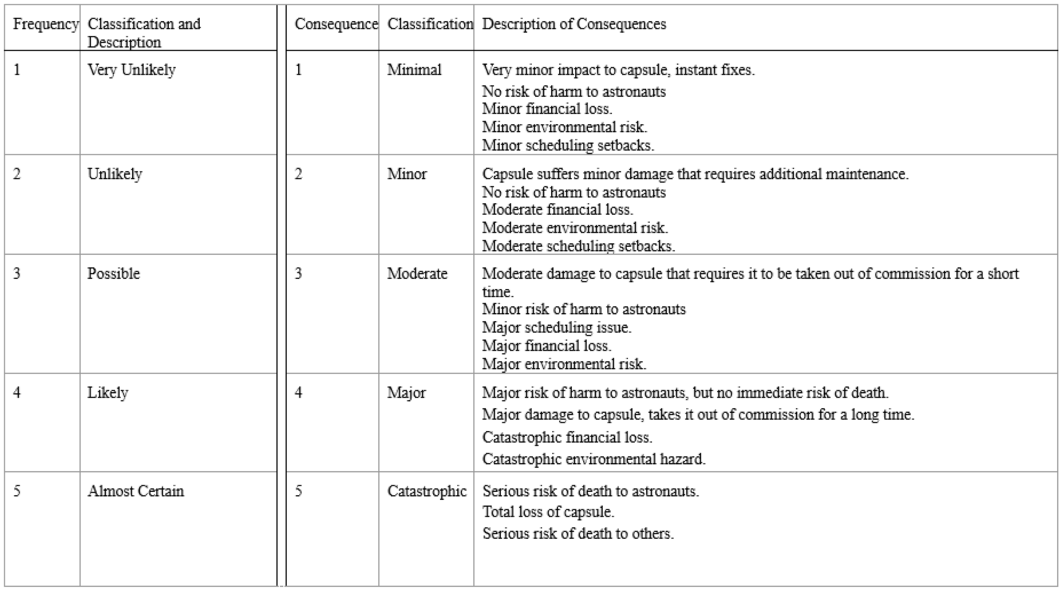


Cost Point	Stage 1					Stage 2					
	2032	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	
Ariane - 62	300000000	375000000	750000000	600000000	525000000	0	0	0	0	0	
Reusable Launcher (e.g. Falcon-9)	0	61640000	369840000	739680000	1787560000	2219040000	2219040000	2219040000	2219040000	2219040000	
Fuel	11628,8	17443,2	46515,2	58144	104659,2	104659,2	104659,2	104659,2	104659,2	104659,2	
Oxygen	36,8	55,2	147,2	184	331,2	331,2	331,2	331,2	331,2	331,2	
Nitrox	368	552	1472	1840	3312	3312	3312	3312	3312	3312	
Cryogenic O2	618,24	927,36	2472,96	3091,2	5564,16	5564,16	5564,16	5564,16	5564,16	5564,16	
LiOH	684,48	1026,72	2737,92	3422,4	6160,32	6160,32	6160,32	6160,32	6160,32	6160,32	
Potable Water	95,68	143,52	382,72	478,4	861,12	861,12	861,12	861,12	861,12	861,12	
Food	13314,24	19971,36	53256,96	66571,2	119828,16	119828,16	119828,16	119828,16	119828,16	119828,16	
Training Cost	14720	22080	58880	73600	132480	132480	132480	132480	132480	132480	
Air Filters	8096	12144	32384	40480	72864	72864	72864	72864	72864	72864	
Refurbishment	65714285,71	86742857,14	199771428,6	210285714,3	307542857,1	236571428,6	165600000	165600000	165600000	165600000	
Initial Investment - ESA Funding	31467146,49	47200719,73	125868586	157335732,4	283204318,4	283204318,4	283204318,4	283204318,4	283204318,4	283204318,4	
Yearly Personnel Cost	17777760	17777760	17777760	17777760	17777760	17777760	17777760	17777760	17777760	17777760	
ESA Ticket Price	386400000	478400000	662400000	920000000	1107680000	1030400000	1004640000	978880000	978880000	978880000	
Non-ESA Nation Ticket Price	148120000	138000000	257600000	708400000	1196000000	1076400000	1052480000	1028560000	1028560000	1028560000	
Private Ticket Price	0	165600000	156400000	386400000	1076400000	993600000	977040000	977040000	977040000	977040000	
Total Cost / year	415008754,4	588435680,2	1463456023	1725327018	2921530996	2757039567	2686068139	2686068139	2686068139	2686068139	
Total Cost / launch	103752188,6	98072613,37	91466001,47	86266350,9	81153638,77	76584432,42	74613003,85	74613003,85	74613003,85	74613003,85	
Total Income / year	534520000	782000000	1076400000	2014800000	3380080000	3100400000	3034160000	2984480000	2984480000	2984480000	
Total Income / launch	133630000	130333333,3	67275000	100740000	93891111,11	86122222,22	84282222,22	82902222,22	82902222,22	82902222,22	
Profit / year	119511245,6	193564319,8	-387056023,5	289472982,1	458549004,3	343360432,9	348091861,4	298411861,4	298411861,4	298411861,4	
Profit / launch	29877811,39	32260719,96	-24191001,47	14473649,1	12737472,34	9537789,802	9669218,373	8289218,373	8289218,373	8289218,373	
Profit / launch (Million €)	29,88	32,26	-24,19	14,47	12,74	9,54	9,67	8,29	8,29	8,29	**Average:**
Proft / launch (%)	28,80	32,89	-26,45	16,78	15,70	12,45	12,96	11,11	11,11	11,11	**12,65**

Fig. 12: Cost per Launch

Type of Risk	Description of Hazard	Description of Consequences	Freq-uency	Conseq-uence	Risk Number	Mitigations	Residual Risk
Political	Worsening of relations between Algeria and Europe	Loss of landing site	2	3	6	Partner with countries near Algeria and splash-down until new landing site has been established	Minimal
Financial Performance	Loss of ESA partnership	Loss of finances	1	4	4	Ensure catering to ESA's needs to maintain steady flow of funding	Very Minimal
Safety – Capsule and Human Life	Engine doesn't start during landing.	Capsule can only land with main parachutes causing a higher landing speed. Poses severe risk to human safety and capsule.	2	5	10	Multiple parachute systems and adaptive propulsive landing and special chairs	Moderate
	Landing on inhabited zone	Could seriously injure or cause deaths of those in area	1	5	5	Reason for landing in desert is to ensure absolute minimal life forms.	Very minimal.
	Failure of single parachute during landing.	Landing without one of the parachutes will increase landing speed. Poses severe risk to human safety and capsule.	2	5	10	Multiple parachute systems and adaptive propulsive landing and special chairs	Moderate
	Hard landing	Longer refurbishment time, capsule might be scrapped	2	2	4	Multiple parachute systems and adaptive propulsive landing	Minimal
Safety- Human Life	Mission Abort	Risk of injury/death for crew	2	5	10	Capsule capable of splash-down, quick recovery	Moderate
	Partial or complete failure of solar panels.	May cause death due to loss of life support systems or communication.	3	5	15	Need emergency power options. Prioritise critical systems.	Moderate
	Failure of Radiators	Excessive heat when exposed to sun. May cause death due to overheating, or damage to life support systems	2	5	10	May require use of space suits for thermal regulation.	Moderate
Environment	Large carbon emissions for transport	Regular flights to French Guyana from Bordeaux would cause high CO_2 emissions.	4	2	8	Use of Canopee boat to reduce emissions significantly.	Minimal
Health	Effects of radiation on astronauts.	Long term/short term effects	4	3	12	Screening for risk factors. Low amount of time in space.	Minimal

Fig. 13: Overall Risk Assessment



Frequency	Classification and Description	Consequence	Classification	Description of Consequences
1	Very Unlikely	1	Minimal	Very minor impact to capsule, instant fixes. No risk of harm to astronauts Minor financial loss. Minor environmental risk. Minor scheduling setbacks.
2	Unlikely	2	Minor	Capsule suffers minor damage that requires additional maintenance. No risk of harm to astronauts Moderate financial loss. Moderate environmental risk. Moderate scheduling setbacks.
3	Possible	3	Moderate	Moderate damage to capsule that requires it to be taken out of commission for a short time. Minor risk of harm to astronauts Major scheduling issue. Major financial loss. Major environmental risk.
4	Likely	4	Major	Major risk of harm to astronauts, but no immediate risk of death. Major damage to capsule, takes it out of commission for a long time. Catastrophic financial loss. Catastrophic environmental hazard.
5	Almost Certain	5	Catastrophic	Serious risk of death to astronauts. Total loss of capsule. Serious risk of death to others.

Fig. 14: Categorisation of Risk