Business Case Study for the Cycler: A Circumlunar Vehicle for Development of Space Tourism and Lunar Infrastructure by 2030

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Abstract

Cislunar space tourism is still a futuristic concept. However, the thrill and innovation that it offers has the potential to attract the attention of High-Net-Worth Individuals. As a result, developing regular tourist-focused cislunar transportation could be an opportunity for space entrepreneurs. Moreover, once established, cyclic lunar transportation might be a factor that could improve lunar business and infrastructure such as those considered for Moon Village. Today, the commercial development of cislunar vehicles is limited by costs and long duration research and development programs, while, the commercial benefits of a reliable transportation system of crew, tools, materials, and supplies are not fully understood. Consequently, the authors present the commercial viability of a cislunar space tourism vehicle utilizing the *cycler concept. This article presents a business case for such a cislunar transportation vehicle and a related portfolio of services that might be realized by 2030. The business case expands previous studies on the Cycler concept proposed by Bombardier, Farr, and Peraldi in 2016. The commercial viability of this cislunar vehicle offers the opportunity for international collaboration as well as the potential for providing access to spaceflights for the space emerging nations. The cislunar space tourism Cycler is envisaged as a modular vehicle that will orbit the Earth and the Moon on a free return trajectory in a 7-day crewed journey (based on a study by Genova and Aldrin). The modular structure provides comfortable to premium travel conditions for 8 paying customers and 3 crew members as well as transporting goods using a cargo unit and a dedicated module to conduct scientific experiments. The article proposes a vehicle architecture using available components with the current Technical Readiness Levels of 6 or higher. This approach identifies technology gaps that need to be addressed to develop cislunar tourism and transportation and demonstrates the limited number of nations that are currently involved in developing these components. Furthermore, the article introduces a risk assessment of the envisaged civil cislunar transportation system, a dedicated financial modeling tool together with potential approach for financing the system through International public–private partnerships.*

INTRODUCTION

The recent pace of technology development offers a potential opportunity for cislunar space tourism to become possible. However, the likely cost of a cislunar adventure will probably be affordable only to an elite group of people—High-Net-Worth Individuals (HNWI). Bringing down the cost of the launch and the investment required to build a cislunar vehicle and maintain operations is key to achieve both a long-term financial viability and a competitive product. The Cycler offers a potentially feasible technological and business roadmap. The Cycler is a concept vehicle based permanently in the cislunar space, which orbits the Earth and the Moon using a free-return trajectory. This solution allows the reduction of the fuel cost as well as continuous operations. Moreover, since the spacecraft does not re-enter the atmosphere, the maintenance cost will be lower compared with the single use spacecraft. To date there has been no private crewed cislunar spacecraft periodically orbiting the Earth and the Moon.

Although the free return trajectory was already used by Apollo 13. This trajectory was planned as an emergency procedure to bring the Apollo service module back to Earth safely and without the need for the fuel in case of engine malfunction. The Apollo13 crew was forced to use the emergency procedure after a rupture of one of the oxygen tanks. The emergency escape procedure was conducted successfully and the ability of using a free return was proven possible.

The Cycler concept has been researched for some time. The first analysis was conducted in 1985 by Aldrin[1] and was later evaluated by Uphoff and Crouch.[2] In the latter, the authors identified that the Cycler could encounter the Moon twice per month (with one window per month for resupply mission) with little to no extra impulse required to power the spacecraft in orbit.

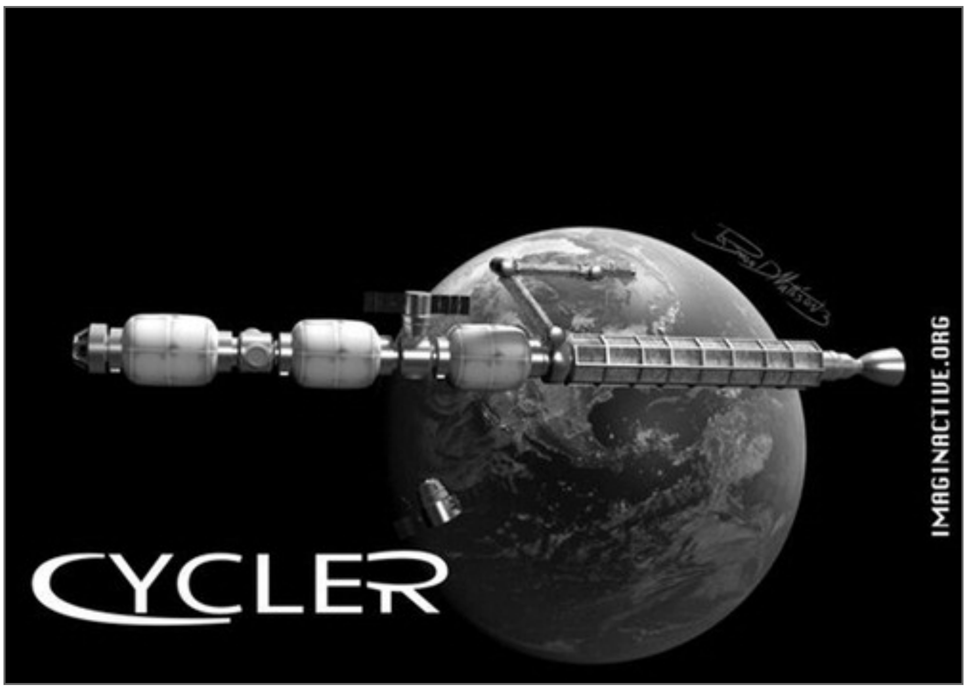
Nowadays, Genova is working alongside Aldrin on calculating the orbit and the flight path for a cyclic spacecraft that would orbit the Moon and provide the ability to take on passengers and cargo on approach to Earth. The detailed study of the Lunar Cycler trajectory reveals the possibility of choosing from different orbits and the number of encounters with the Moon and the Earth. To offer a tourist-focused experience with a view of the lunar surface the Cycler will utilize the "Shamrock orbit" described by Genova,[3] which provides a 7-day journey every 19 days. This serves as an input to evaluate the customer capacity in a year of operations. Under the assumptions set for this evaluation, the number of profit days in a year is 98 and the maximum number of passengers is 128. Moreover, the published articles define the required velocity for orbital maneuvers and orbit maintenance, which supports the estimation of the required fuel and resupply mission frequency.

The aforementioned research does not consider the technology required to build a Cycler and the timescales to introduce it in operation. Neither the business case for its assembly and operations were previously evaluated. Thus, the authors attempted to estimate if there is a business case for a lunar Cycler.

THE CYCLER CONCEPT

The Cycler evaluated in this article was based on the concept proposed by Charles Bombardier, Dr. Rebecca Farr, and Dr. Olivier Peraldi in 2016.[4] The concept is proposing to use the available technology and transferring it within its current capabilities (where possible) such as SpaceX Dragon capsule, Bigelow Aerospace B330 expandable modules, and Cupola windows (currently used in the International Space Station [ISS]).

The Cycler concept has a capacity of up to 8 passengers and crew of professional astronauts to travel on a 7-day return journey around the Moon.[4] The authors of this article proposed a variant of this vehicle, which will allow to increase the number of passengers to 12 and 4 crew members. The solution is aligned with the multiplication of the capacity of the Soyuz capsule, which at the moment can contain 3 individuals—as recently agreed by Roscosmos.[5] The spacecraft offers private sleeping modules along with a separate dining area, social area, and a lounge. An artist's impression of the Cycler is presented in *Figure 1*.



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Furthermore, the Cycler offers the opportunity to establish a regular transportation system to the lunar orbit and surface, which will enable transportation of cargo between the Earth and the Moon. The authors are focusing on evaluation of the status of the technology and the commercial attractiveness for the investors willing to develop the circumlunar transportation vehicle as well as technical commercial challenges and legal limitations. This project was researched as part of the International Space University MSc Individual Project. The full report is available on request.

CURRENT CISLUNAR JOURNEY OFFER AND MARKET POTENTIAL

The authors evaluated 2 companies that are currently offering circumlunar journeys for which they have, reportedly sold tickets. These companies are: Space Adventures and SpaceX.

Space Adventures intends to offer a staged journey aboard a Soyuz spacecraft. The customer will join the ISS for 10 days to adapt to life in space. In the next stage, the customer will be moved to a Lunar Module for a circumlunar journey. The spacecraft will be joined with the Lunar Module in low-Earth orbit (LEO). Space Adventures signed a Memorandum of Understanding with Russian Space Agency Roscosmos to use the currently available technology. Despite those initial steps, legally binding contract between Space Adventures and Roscomos for the service, hence it is difficult to estimate when the first launch will occur. This proposal offers the customers a journey in a habitable module larger than a Soyuz capsule. However, the offer is limited to only one living compartment for 2 passengers.[6]

Alternatively, SpaceX is proposing a private trip around the Moon onboard the crewed Starship, which is reusable. The spaceship must undergo the design and testing approval processes before taking any passengers. However, at the moment the first trip is scheduled for year 2023.[7] The deposit has been paid by a private customer, a Japanese entrepreneur, and the mission was dubbed dearMoon project. Based on SpaceX website it is not clear on how many passengers will be able to be carried by Starship. However, other sources state that the Starship, when developed, will have a capacity of up to 100 passengers.[8] It is not disclosed how much room and comfort will the customers be offered. However, a lack of comfort during the trip may result in less pleasant experience and therefore, less interest for the future missions.

To best estimate the market size for the space tourism the authors considered the number of Ultra-High-Net-Worth Individuals (Ultra-HNWI) that will be the potential customers for the journey. The Ultra-HNWI metric is typically used by banks and economists to define people, who possess liquid assets greater than 30 million USD (~26.5M EUR). According to the 2020 Ultra Wealthy Population Analysis Report prepared by Wealth-X research company, the projection of the number of Ultra-HNWI is over 353 thousand people with a combined wealth of 43 trillion USD by year 2023[9] (~38Tn EUR), which is expected to continue to grow with time. Deriving the average wealth per individual it is more than 121 million USD per person (~107M EUR)—enough to afford a journey to space.

However, considering that the wealth is not evenly distributed and providing a conservative approach to the calculations it is assumed here that only 1% of the Ultra-HNWI will be able to afford and willing to embark on a cislunar journey. This gives an approximate number of 3,500 potential customers and a market size of 430 billion USD (~380Bn EUR). Considering one trip per person at a price of 125 million Euro per person. These individuals will be the primary pool of potential customers for future space tourism.

There is some recognizable validation already for HNWI paying large sums for access to space. Among the examples are: the recent SpaceX "Inspiration 4" mission, all-civilian flight to LEO and Blue Origin flights to the edge of Space.

The market size gives investors and traders an incentive to seek business opportunities in the space tourism discipline. Although, the circumlunar adventure is being advertised as possible, it has not yet been accomplished. Therefore, circumlunar journeys will leave doubts about their feasibility and profitability until they are delivered.

EXISTING TECHNOLOGY TRANSFER AND COMMERCIAL FEASIBILITY

Acknowledging the potential commercial opportunity, the authors chose to assess a commercial feasibility (a business case) of building and operating a circumlunar spacecraft to be assembled from currently available components (of TRL6 and higher). The base assumption for this project is for the Cycler to provide a commercial return within a decade from setting up the company.

Habitable Modules

The Cycler must be assembled from the modules that will provide all passengers and crew with a habitable zone equipped with environmental control and life support system. The Cycler must contain docking ports and the nodes to connect modules. To provide comfort, The Cycler should give the passengers and crew the access to private areas for sleeping and sanitary compartment as well as space for gatherings such as dining area, viewpoints. A secure area to conduct experiments and a cargo compartment will be a benefit to bring in additional revenue.

At the time of research, the most suitable available modules to assemble the Cycler were the Bigelow B330 and B2100 mainly because of their built-in autonomous life support and power equipment and the technology, which has been developed to TRL9 and tested in space environment. As the proposed Cycler concept contains several modules, the authors analyzed the delivery schedule. The input from Bigelow Aerospace indicates that, given the bulk order, the company will be capable of delivering the first module within 42 months, the next one 28 months after, with the third one to be processed in 22 months from delivering the previous.[10] Given the duration of the manufacturing process and the fact that the Cycler requires 4 B330 modules, the Cycler can be assembled in orbit on a phased basis with modules being added once manufactured to provide partial revenue until the assembly is finished. Alternatively, the modules from other manufacturers were considered to ensure the speedy delivery. The authors consider an opportunity in reusing the modules designed for the purpose of ISS assembly.

Some of the modules were built as redundant units. However, due to the lack of funding, they were never sent into the orbit. These modules are safely stored and, therefore, the authors consider an opportunity to purchase them and reuse for the Cycler assembly. Alternatively, the authors consider an opportunity to reuse the design and production line of the modules, which are being used in ISS and might be available to purchase, acknowledging the delay in setting up the contractual arrangement and the cost of establishing the production line. The examples of the modules are: Node3 Cupola windows, Canadarm2, and Prichal docking module.

The delivery of the modules was therefore split in Phases of operation to ensure that the Cycler can start boarding paying customers and crew while the subsequent modules are being delivered to increase the capacity and therefore the profits. The timeline considers an immediate commencement of the company operations and reserves a period for obtaining the funding. The proposed timeline is presented in *Table 1*. The forecast for the expected module delivery is presented in *Figure 2*.

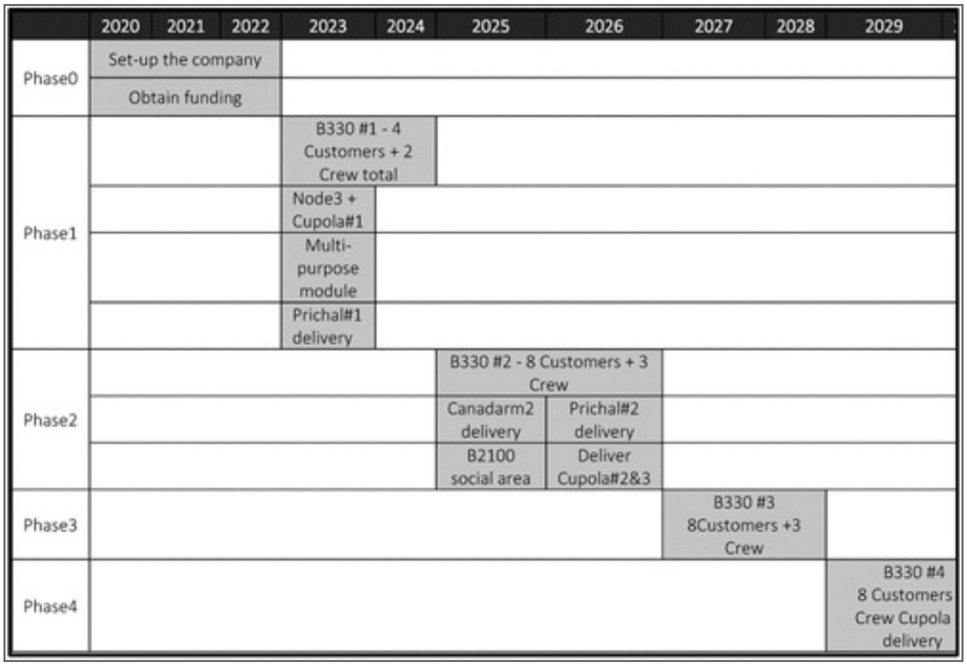


Table 1. Proposed Module Delivery Schedule and Cycle

Name	Duration	Activities	No. of People Po	
			Customers	C
		Set-up company operations and making **Obtain investment**		

Phase 0	Q3 2020–Q2 2022	funding Initiate an order for B330 and B2100 modules Book-in first customers Operate commercially utilising Soyuz as a vehicle Deliver first B330 module into orbit and deliver first crew of 2 people Deliver first Prichal docking module and attach to B330 module Deliver Cupola window no. 1

		along with Node 3 module and assemble with B330 module	
		Deliver multipurpose module for pilots	
Phase 1	Q3 2022–Q3 2022	Begin commercial operations with 4 customers	4
		Operate commercially utilising Soyuz as a vehicle	
		Deliver second B330 module to fit 8 customers and 3 permanent crew	
		Deliver Canadarm2	

		to rearrange the module Deliver B2100 social area module Deliver second Prichal module	
Phase 2	Q3 2022–Q3 2026	Deliver Cupola windows nos. 2 and 3 Operate commercially utilizing Soyuz and SpaceX Dragon as a vehicle	8
Phase 3	Q3 2026–Q3 2028	Deliver third B330 module to provide comfort to the Customers Operate commercially	8

		utilizing Soyuz and SpaceX Dragon as a vehicle Deliver fourth B330 module to provide comfort to the customers	
Phase 4	Q3 2028–Q3 2029	Deliver Cupola window no. 4	8

Passengers and Crew Delivery to LEO

Considering that the Cycler will be permanently based in orbit, the method of transporting passengers and goods on a regular basis to the Cycler in LEO was considered. Given the Soyuz mature manufacturing and assembly techniques and the scale of manufacturing with well-established manufacturing processes, it is considered as a trusted supplier of the vehicles required to deliver Cyclers' Customers on a regular basis. Additionally, the flight track record and reliability make the Soyuz to be considered as a preferred vehicle for transportation from Earth to LEO. However, the low capacity for the paying passengers in one flight and the necessity to absorb the high cost of the pilot launch by the company, which will be operating the Cycler, makes this solution commercially unattractive.

The authors propose a solution to offer public authorities and private companies to use the pilot to conduct experiments onboard. This opportunity will offset the cost of the pilot's launch to orbit and was built into the assumptions of the business case. It is likely that launch might be disrupted by technical, environmental, or political issues. It might result in missing the launch window for delivering the Customers to the Cycler. It is recommended to diversify the launch providers and consider the future opportunities to delivery of the Customers to the Cycler. Hence, this business case analyzes the costs of alternating the vehicles between Soyuz and SpaceX Dragon and having a crew of 2 permanently based on the Cycler with a rotation frequency of 4 months. In the future it is presumed to be possible to book the flights with a particular launching company based on the forward demand and sold tickets to ensure the full capacity of the Cycler is utilized. However, after the initial phase of operations and once the capacity of the Cycler is ramped up to 8, the additional mean of transportation will be added to the portfolio (SpaceX Dragon) due to its lower costs, alteration in the launch provider.

THE COMMERCIAL FEASIBILITY OF THE CYCLER

The technical feasibility section presented solution for the Cycler assembly and proposed a schedule for the vehicle assembly phases. Also, the capacity of the crew and passenger was studied to ensure the efficient use of the paid space onboard the LEO transportation capsules and the usage of space onboard the Cycler modules. There might a split between the Cycler being constructed by one company and operated by another. However, for the purpose of this article, the authors proposed to analyze both activities as a system, giving the example of the Cycler's baseline recurring costs.

Cost Modeling

The cost breakdown for the Cycler's build and operations are summarized were assembled according to the proposed phases of the project. The following categories were analyzed:

1. **Sunk costs—the nonrecurring costs of assembly and build of the Cycler structure consist of:**

    Structure cost—component cost breakdown

    Structure launch into the orbit—the cost of launch of each component

Cost of labor—the specialist wages and launch costs required for a human assistance to assemble the modules in orbit

2. **Recurring costs—the annual costs the Cycler operations consist of:**

    Staff cost—wages for the crew and pilots

    Resupply mission costs—the cost of supplies and delivering them to the Cycler

    Maintenance and repair costs—the cost of specialist and tools for maintenance

    Customer support costs—the cost of training, mission control, and medical support

A mathematical model was created to support the calculations of the forecasted revenues for the Cycler. The technology presented above served as an input to the cost model. Based on the model, a further sensitivity study was developed by measuring the crucial Key Product Indicators such as Return on Investment and Net Present Value (NPV).

The model depends on the set of the key parameters that are commonly used to evaluate the investments. The following parameters that are presented in *Table 2* serve as an input for the commercial calculations:

Table 2. The Inputs to the Mathematical Model

Name	Value	Reference
Cash interest rate	3.92%	Bankrate[11]
Brokerage commission	4.0%	Kagan[12]

Depreciation period—life duration of the Bigelow Aerospace Modules	15 years	Kelleher (2020)[13]
Existing assets depreciation rate	7%	1/life duration
Loan maturity	20 years	Input
Cost of equity	8.32%	Damodaran[14]

The Cycler requires high initial investment in the structure and no revenue before the commencement of operations. This makes the investment risky and less attractive to banks. Therefore, any potential bank funding will be more likely to be obtained after the deposits are taken from the Customers. Therefore, the assumed ratio between the debt and equity financing was set to 30/70. The investment cost throughout the Phases is presented in *Table 3*. The split of operational costs is presented further in *Figure 3*.

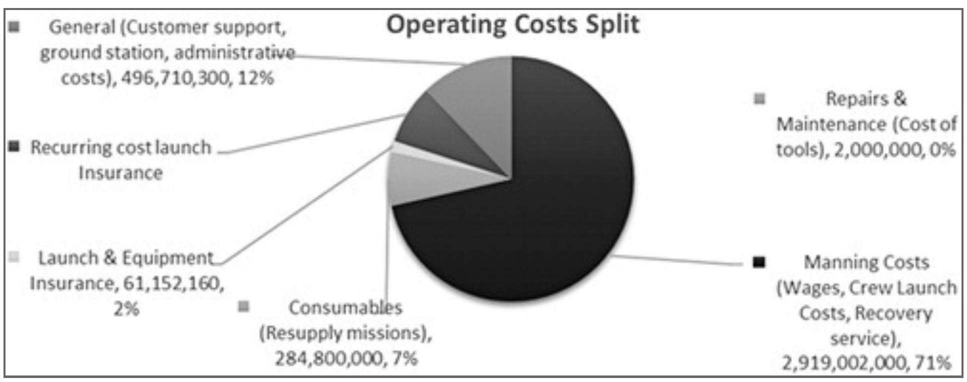
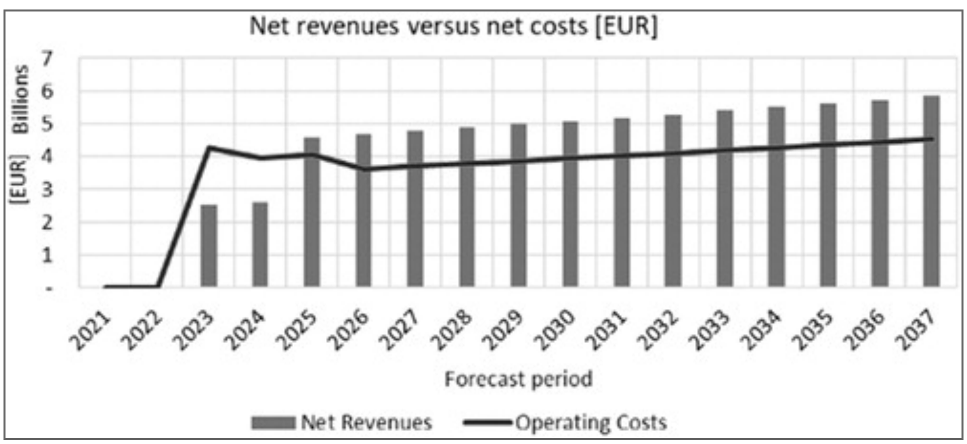


Table 3. The Cycler Investment Costs

M€	Phase 1	Phase 2	Phase 3	Phase 4

Sunk costs (including launch)	**983.4**	**2,220**	**256.5**	**526.3**
Operations	**783.5**	**735**	**735**	**735**
Staff costs (75% is pilot launch cost)	**2,919**	**2,521**	**2,521**	**2,521**
Revenue	**2,539**	**4,428**	**4,428**	**4,428**

As presented in *Figure 4*, in the first phase of Cycler's operations, the recurring costs significantly exceed the revenues from the sold tickets. This is mostly due to the high costs of launching Soyuz pilots. The costs are covered by the Cycler operator. In the following phases, the net revenues exceed the net costs starting from Phase 2 of the Cycler operations and the project becomes profitable. The calculations assume that 25% of the pilot launch costs will be covered by third parties (public or private organizations) to ensure profitability. This number was derived based on an optimization study, which was performed to assess the critical pilot launch number required to provide positive Internal Rate of Return (IRR) and NPV.



Customer Ticket Price: Sensitivity Study

Information

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A sensitivity study was conducted to assess the minimum ticket price with a criterion to achieve NPV equal to zero. The lowest price for the ticket, which resulted from the optimization, is around 34 million person (34,000,000 EUR). While the reduction of the ticket price may have a positive effect on gaining new customers, the NPV must be kept positive to ensure the healthy valuation of the business and attract investors. Based on the sensitivity study, the most appropriate ticket cost to satisfy both abovementioned requirements is 30 and a half million EUR. This ticket price was used for further calculations. It is noted that the ticket price is kept steady throughout the Cycler operational period. Further optimization can be conducted to reduce the ticket price or reinvest in expanding the Cycler.

The calculated revenue assumes that 25% of flights the public states or private organizations will cover the cost of the pilots' flight to the Cycler to significantly reduce operational costs. The sensitivity study was conducted to assess the optimum per cent of pilots' flights coverage to provide positive IRR and NPV. The pilot cost coverage should be recurring for at least 3 years until the beginning of Phase 2 when additional mean of transportation to LEO is introduced. It is expected that by year 2025 SpaceX will provide commercial operations being able to deliver 6 customers to the Cycler. However, as the Cycler capacity will grow, it is planned that it will require an additional crew member (3 in total). Hence, the transportation of the crew member is planned to be executed onboard additional Soyuz capsule that can be left docked onto the Cycler. This solution will provide an emergency escape seat to the resident crew member. Therefore, this solution offers an opportunity for a long duration scientific mission for the pilot who will deliver the crew on a 4-month rotation.

The results of the financial modeling under presented assumptions show that the Cycler is an investment, which will yield a positive return within a decade. The calculated IRR stands at 15% and NPV at 1,425,000 Euro. Given continual occupation and accident-free operations, The Cycler presents an attractive business proposal and service. Although, the first phase of operation presents a challenge with the very high operational costs to overcome. Therefore, any potential investor will face significant upfront investment risk. Nevertheless, some solutions are proposed to bring additional revenue to the business and ensure continuation of the operation to interest investors. Based on the assumptions explained later in this article, the Cycler's annual passenger capacity is 112 people. Hence, considering the market size for the potential customers of 3 and a half thousand people (as explained in the introduction), it provides an opportunity to continue the Cycler's operations for 27 years.

Commercial Opportunities

Opportunities for future development are proposed to add profitability to the investment.

Some examples that can be considered in the future analyses are provided:

1. **Lunar cargo—transportation of the equipment and supplies to support the growth of the lunar settlements and cargo services to bring resources from the Moon to the Earth's orbit. However, this solution requires a development of a Lunar Lander and there is no reliable design available commercially at the moment.**

2. **CubeSat launch—providing launch services from onboard the Cycler to the Lunar orbit, similar to Nanoracks Bishop airlock currently available in ISS. This solution requires an investment of ~$20M USD (~17.5M EUR) and the return and demand need to be analyzed.**

3. **Conducting paid experiments—another opportunity is to provide a turn-key solution offering qualified staff and tools to conduct experiments on behalf of a company or a nation.**

Although the proposed opportunities might offset some of the operational costs of the vehicle, the challenges of the available technology need to be considered. To provide lunar cargo the lunar lander is required. The Cycler has an additional docking port, which could serve this opportunity. Although it is deeming desirable as the performed existing technology research concluded that there is no lander available that would be developed to the TRL6 and higher. Also, a development of a vehicle capable of delivering the cargo down to Earth is required. At the moment only SpaceX Dragon Cargo can carry cargo down to Earth, but with a limited volume.

Investor Landscape

The Cycler requires a substantial upfront investment to cover the cost of setting up the company, the cost of the structure, and its launch to the orbit before any profit can be considered. Of course, the deposits for the tickets can be collected from the customers ahead of the journey. However, according to the presented, results the recurring costs of the Phase 1 of Cycler operations are significantly overcoming the revenues.

As noted in the previous sections, the available financial instruments for the project of the scale of the Cycler are debt (a loan provided by a bank) and an equity funding (cash investment provided by private investors). While obtaining the bank loan is possible, the banks prefer stable investments with solid returns to ensure the steady and timely repayments. The Cycler cannot ensure either of these due to the high-risk nature of the business and dependence on the customer market (the risks are further evaluated in the full Report). Moreover, Phase 1 does not secure the positive cashflow and, therefore, does not secure repayment of the instalments to the lender. Therefore, the recommendation for the funding of the Cycler is to first seek a leading private investor (an ultra-HNWI) who will have a personal motivation to complete the project. A second stage would be to seek support from the business angels and venture capitalists. Lastly, the debt funding can be sought to complete the investment. However, a steady flow of revenue is required to be awarded a loan.

Moreover, the trend shows that most of the companies offer side services to provide additional revenues.

TECHNOLOGY CONSIDERATIONS AND LIMITATIONS TO CYCLER OPERATIONS

Modules Technology

When analyzing the currently available technology to assemble the Cycler, the authors encountered several issues that might influence the work on the Cycler. The first challenge is the delivery of the modules and structural components. The company, which has a proven design of the preferred modules (Bigelow Aerospace), will not cope with the capacity of delivering the modules at once. The company estimated the time between modules delivery for 22 months (assuming the best-case scenario). However, there are doubts with regard to the company's operations with predictions of closing of operations. Thus, the modules might not be available for delivery at all. Therefore, the market gap is identified. The authors identified this risk of losing the supplier for the modules and, therefore, included other modules as a solution. Although, there is no commercial production for the space components, some of the modules manufactured for ISS can be utilized.

Delivery to LEO

More than 70% of the operational costs of Phase 1 encompasses the cost of the delivery of the Soyuz pilots (over 2 billion EUR). This cost will need to be covered by the Cycler operator. This cost, however, can be recovered using an existing solution. At the current ISS operations, the pilot of the Soyuz performs experiments onboard. Hence, it is proposed to invest in a module serving as an international laboratory that can be used free of charge for states and companies who are willing to pay the fee for pilot training and cover the cost of their Soyuz flight and any customized laboratory equipment.

International Regulations

The increased demand in crewed orbital flights will require a careful consideration of the air traffic control regulations to ensure the safety of the passengers and crews.

According to the final ruling of FAA Human Space Flight Requirements for Crew and Space Flight Participants, it is a requirement of the spaceflight operator to train every member of the crew to carry out their role during the spaceflight. The training content and time may vary dependent on the role that the crew member is fulfilling. As the industry is inexperienced, there is no strict guidance on the training content, and it is evaluated on the case-by-case basis. The international regulations must be considered to ensure the uniform safety baseline across all countries and launch providers. The variation in the safety requirements between states of the launch providers and/or hardware providers might have an impact on the business case.

Connections Between Modules and Additional Non Recurring Expense Costs

The interaction between different modules is out of scope of this article. However, the proposed modules might not have a capability to interact with a product of a different supplier. A further study is required to ensure that connected units can perform as a system and its impact on the investment might be significant.

Risks

The Cycler will operate in an extreme environment where the structure and the personnel will be continuously exposed to many hazards. The operator must account for any unplanned threats that may impact the business. Hence, the appropriate risk management plan is required to monitor and document the risks. There are number of commercial and technical risks that have direct impact to the Cycler business case within set criteria.

Based on the analysis conducted by the authors, the highest impact and probability is caused by the commercial risk of no interest in covering the launch costs of the pilots. This situation will result in high recurring costs to the business and it will impact the profitability of the vehicle. The risk of not being able to secure the launch provider may cause damage to the Cycler's financial situation. The full report contains the mitigation actions and risk matrix with scoring. The main technical risks are: Frequent Passing through Van Allen Radiation Belt, a potential collision with space debris or a docking vehicle and a fire hazard onboard the Cycler. Any technical issue onboard the Cycler will result in damage to the brand and reputation, which will impact the number of interested customers. However, mitigation actions are proposed to lower the significance of the damage.

The hostile environment of spaceflight needs to be considered as it will cause a long-term damage to the bodies of people onboard the Cycler. Although the results do not have direct impact on Cycler operability, the investment in the protective measures should be accounted to provide the sense of safety to the potential customers.

Apart from the technical and commercial risks mentioned above, there are also environmental and medical risks that the crews and customers will be exposed to. The authors did not include them in the risk matrix as they do not cause a direct threat to the business. However, they need to be listed as they will be a part of the informed consent signed by the customers and they need to be addressed for the employees.

CONCLUSIONS AND RECOMMENDATIONS

By following the Observing current space tourism market development, it becomes apparent that only a handful of companies are trying to offer new services and experiences to potential customers. Although the development of spacecraft and hotel-like structures is pictured as progressing in the media, so far only one company (Space Adventures) has managed to facilitate the actual flights for nonprofessional astronauts and only one company (Bigelow Aerospace) has managed to test the commercial module in space environment. Looking at the investor landscape and the organization of the most advertised space tourism providers, it appears that most of the companies are sponsored by ultrawealthy individuals who are passionate about commercial spaceflight. The companies are providing a range of services to stay profitable until the first commercial flights are realized.

The authors consider the return journey to the Moon as a next big step in the commercial space tourism offer. Therefore, the Cycler is considered as a means of delivering a premium experience during the tourist-focused return trip to the Moon, based on the offering of capacity for social areas, private areas, and windows, such as Cupola, used in ISS.

The industry of commercial flights must mature to secure the logistics for the Cycler operations. Also, the supply chain for the components needs to be developed to provide components and spare parts and maintenance support once the number of commercial modules operated in space will increase.

The following recommendations are proposed for the Cycler operator to ensure profitability and steady operations:

1. **To gather the funding required for initial**

investment for the Cycler it is recommended to identify a wealthy investor who will personally support the project backed with support from the hedge funds and venture capitalists.

2. **Invest in marketing and advertisement of the business to ensure the flow of the customers and create an aura of an elite spaceflight experience.**

3. **Sign the agreements with the launch providers in advance to selling the tickets to make sure the full occupation of the Cycler can be realized. Also, involve launch providers in the investment in the Cycler for security of the launcher profits and potential discounted rates for the launch.**

4. **Provide additional services to secure the cash flow to the business.**

5. **The ticket price per customer should be kept steady throughout the Cycler operational period. Further optimization can be conducted to reduce the ticket price or reinvest in expanding the Cycler.**

The following recommendations are proposed for the Cycler operator to ensure safety and comfort of the passengers:

6. **Ensure the subsystems' redundancies in the module design to mitigate technical risks.**

7. **Analyze that different modules can be assembled and work together as a system.**

8. **Follow NASA guidelines on ergonomic and safety of the Cycler interiors.**

9. **Ensure that both crew and spaceflight participants are trained in emergency situations.**

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