CentraleSupélec

Moon Mining Project Final Report

Human Systems Integration

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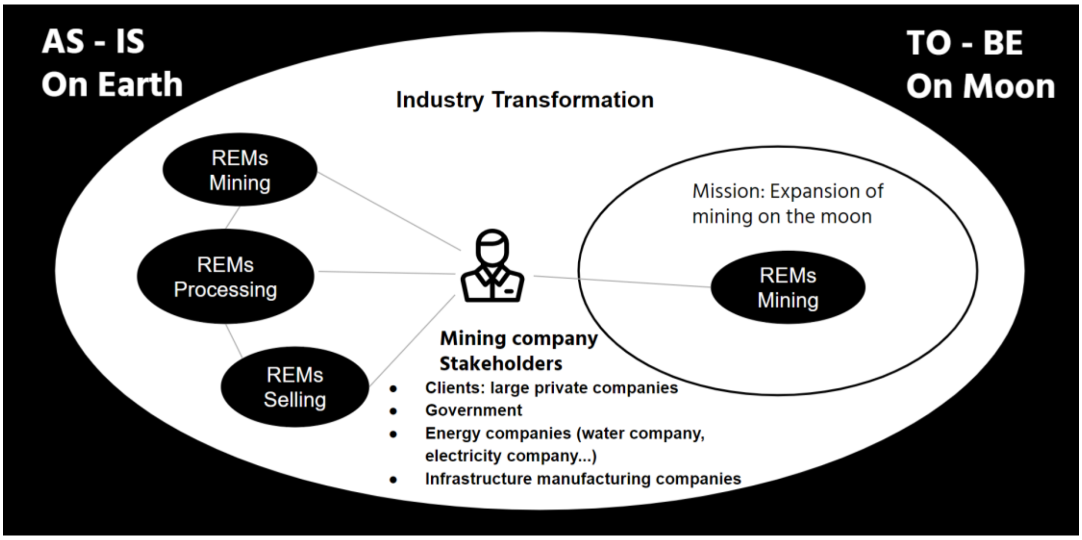
I. Project context and objective

Rare earth metals are crucial to our modern world, powering essential technologies such as electric cars, cell phones, military equipment, and fluorescent tubes. The NASA report indicates that China currently produces 90% of rare earth metals. [1] However, with the growing increased demand for these elements, China has claimed that its reserves may only last for 15 to 20 years. Therefore, sustainable exploration of rare earth metals on the moon has become an inevitable path for humanity to pursue.

In this context, Moon Rabbit, a renowned rare earth mining company with exceptional expertise in extracting valuable metals on Earth, is now expanding its operations to a new frontier - the moon, with the aim of rapidly securing a significant market share. The business goal is to help large private companies and governments mine rare earth on the moon to make profits.

The transformation project will involve conducting extensive research on the extraction methods and technologies that can be used on the moon, identifying potential partnerships and collaborations, and developing a comprehensive plan for sustainable rare earth mining operations on the moon. The project's success will be measured by the number of rare earths extracted, the profitability of the operations, as well as the number of new job opportunities created, and compliance with the balance of social and economic benefits.

II. Project Overview



The current business of Moon rabbit is all focusing on the earth, mainly including three important parts: Rare earth mining, rare earth processing, and rare earth selling. Through this industry transformation project, we will expand our mining business to the moon so as to make more profits.

Among all, the stakeholders of the project are very crucial to the achievement of success. Here we make a brief analysis of each of them.

1. Large private companies

They are the most important clients of our company, all our businesses are concentrating on them and we need to provide excellent mining quality and service for them, at the same time we have to convince them to invest in us during the whole project, otherwise, we might face the risk of lack of the initial capital and free cash flow.

2. Government

The government is also our main client, we need to fulfill all their mining requirements and make them satisfied meanwhile we need their legal support for the mining permit, also there might be legal restrictions that we have to respect. So building a good and strong relationship with the government is very important.

3. Energy companies

Energy companies such as Total, EDF, Engie, etc. They are our partners and provide us with indispensable fuel sources so that we can successfully transport our rare earth from the moon to the earth.

4. Infrastructure manufacturing companies

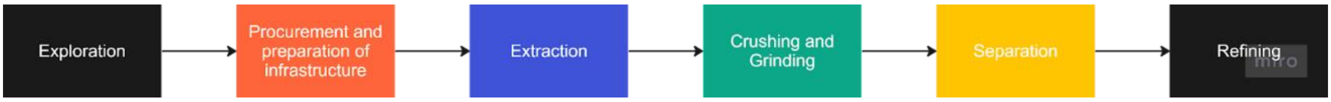
All our mining machines and robots are purchased from these companies, we should build long-term collaborative relationships with them and negotiate to get the lowest purchasing prices.

5. NASA agency

NASA is a crucial partner in our successful mining, we need their support to send our mining robots and machines to the moon, and after mining, we also need their help to transport the rare earth back to the earth.

III. Current technology and methodology for rare earths mining on the earth

In order to better conduct the mining on the moon, we need to first have a good understanding of current technologies and methodologies of mining rare earths on the earth. Typically, the mining can be divided into the following steps [2]:



1. Exploration: Locating possible deposits is the initial step in the exploration process. In order to find places with a high potential of holding rare earths, geologists typically employ a range of approaches, including geological investigations, aerial surveys, satellite images, etc.
2. Procurement and preparation of mining infrastructure: Before beginning actual mining, we must acquire all necessary infrastructure and equipment.

3. Extraction: After everything has been properly prepared, the next stage is to extract the rare earth elements from the nearby rock. Many techniques, such as solution mining, open-pit mining, and underground mining, can be used to accomplish this.
4. Crushing and Grinding: Following mining, the ore containing rare earth elements is often crushed and powdered into minute particles. This enables separating the rare earth minerals from the other minerals in the ore easier.
5. Separation: It can be difficult to separate rare earths from other minerals since they are often present in extremely minute concentrations inside the ore. Gravity separation, magnetic separation, and flotation are just a few of the separation methods that can be applied.
6. Refining: Following their separation from other minerals, rare earth minerals are purified and refined to remove impurities.

IV. The challenges and possible solutions of lunar mining

The Moon's surroundings are hugely distinctive from that of Earth, we need to recall numerous challenges.

1. Mining operations on the Moon are complicated by the extreme temperatures. Temperatures can range between -173°C at night and 127°C during the day. A temperature difference of this magnitude can make it difficult to maintain equipment and work for extended periods of time.

2. The harsh environment of the Moon is covered in a layer of fine dust known as regolith, which can cause problems for machinery. Furthermore, due to the Moon's lack of atmosphere, it is constantly bombarded by solar radiation and micrometeoroids, which can damage equipment and be hazardous to human health.

3. The Moon's distance from Earth makes transportation and communication hard. Delays in communication between the Moon and Earth ought to have an effect on real-time mining operations.

4. Because of the lack of readily available sources of power on the Moon, any mining operation will need to deliver its personal energy supply. While solar panels are a popular alternative, the lunar night-time lasts 14 Earth days, making it hard to hold energy on during the lunar day-night time cycle.

5. The Moon has restrained assets which include water and oxygen. Any mining operation will want to deliver its personal assets or discover a manner to extract them from the lunar floor, which can upload changes and challenges.

We've diagnosed principal challenges: mining in such harsh environments and the excessive cost of launching and transporting fuel from Earth.

We investigated 3 solutions for the primary challenge.

The first one is for the operator to manipulate the mining machines from Earth. It permits optimum operator safety because the operators can manage the machines from a faraway region on Earth without bodily being on the Moon. This ought to reduce the threat of injuries and accidents that would arise if operators have been operating on the lunar floor. But the space between the Moon and Earth might cause signal delay and inaccurate feedback, causing issues with accurately controlling the machines and receiving feedback. As a result, the operation might also additionally require extra time and assets to complete, leading to higher costs.

The second one is to have the operator mine on the Moon. It will enhance excavation performance and accuracy because the operator might have extra direct management over the machines and will higher determine the geological conditions. This ought to assist to lessen the time and fees related to the operation. However, in order for humans to work on the lunar surface, additional infrastructure and resources would be required to ensure their survival and health in the harsh lunar environment. This could include establishing a lunar base or habitat, which would require a significant investment in equipment, materials, and personnel. Some of the demanding situations related to organizing a lunar base encompass the intense temperature variations, the shortage of environment and water, the ability of lunar dirt to harm gadgets and damage human fitness, and the multiplied radiation exposure. Overcoming those demanding situations might require superior generation and expertise, which can upload to the fees of the operation. Additionally, having people on the lunar floor additionally introduces ability dangers and protection concerns, that can affect the general fees and feasibility of the operation.

The third one is to ship excavation machines to the Moon and release a manned spacecraft with astronauts into orbit across the Moon. This solution is much less costly than the second one due to the fact we do not want to construct greater bases on Earth. Moreover, we have enough experience launching spacecraft, which makes it safer for the operator. Also, this solution reduces signal delay since the distance between the spacecraft and the Moon is much smaller than the distance between the Earth and the Moon. Additionally, compared to option one, where engineers can only control the machine remotely but have no way to fix errors in time, this option solves this problem.

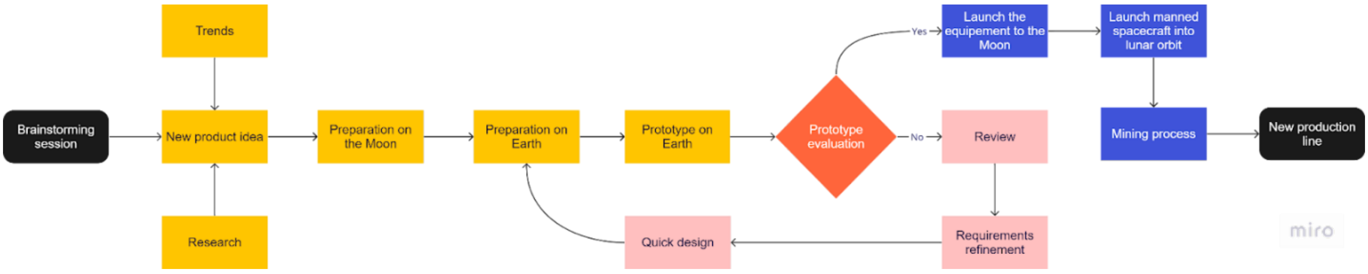
Regarding the second challenge, we suggest maximizing the usage of the sun's electricity on the Moon. There are abundant solar energy resources on the Moon, making it a renewable and sustainable source of energy that does not require any fuel to be transported from Earth. This means that it would significantly reduce the overall amount of fuel needed for mining and would make mining more cost-effective in the long run. Moreover, solar panels are lightweight and compact, which would make them easy to transport to the Moon.

We plan to use solar energy to produce fuel through a process which is electrolysis. In electrolysis, an electric current is passed through water to separate it into its parts of hydrogen and oxygen. The process of electrolysis involves placing two electrodes in a container of water, which is typically mixed with an electrolyte (such as potassium hydroxide) to make it more conductive. One electrode is connected to the positive terminal of a power source (such as a solar panel), while the other electrode is connected to the negative terminal. When the electric current is applied, it causes the water molecules to break apart into hydrogen and oxygen gas.[3]

The hydrogen gas that is produced in this process can then be used as a fuel for various applications, including as a fuel for rockets or other spacecraft. When hydrogen is burned, it combines with oxygen in the air to produce water vapor and energy, which can be used to power engines or generators. The use of solar energy to produce hydrogen fuel through electrolysis is an attractive option for space missions, as it provides a renewable and sustainable source of fuel that does not require any resources to be transported from Earth. Additionally, the byproduct of burning hydrogen is water, which can be used for drinking, growing crops, or other purposes.

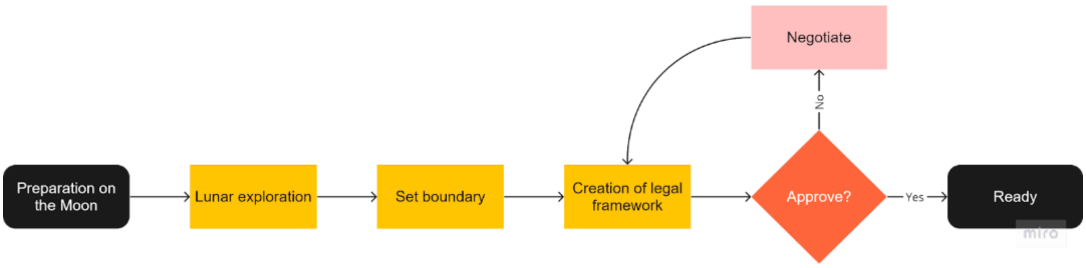
V. Prototype of the lunar mining process

Considering our objective, we have designed an overall flowchart for our lunar mining plan. It is shown in the figure below.



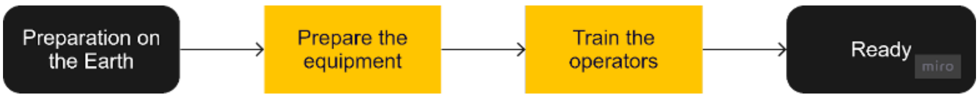
First, as a mining company, our team brainstormed internally to explore the possibility of mining elsewhere in a resource-constrained circumstance. We found that there is now a growing trend to exploit the moon, while the study above also proves the possibility of mining the moon. Therefore, we came up with a new product idea, which is mining on the moon.

To reach this goal, we start with the preparation phases on the moon and earth, respectively. For the preparation phase on the Moon,



We will first conduct an intensive exploration of the Moon, with a detailed study of rare metals on the Moon. The process of exploration is more similar to that on Earth, since with the existing technology, we have been able to obtain the distribution of rare earth resources through lunar rovers or satellites.[4] What we need to explore additionally are the environmental conditions, including extreme diurnal temperature differences, varying z-gravitational acceleration, and the risk of long-term exposure to space rays and solar storms. In response, we need to gain insight into their effects on our equipment to ensure they function properly. Then, we set boundaries where we decide to mine to guarantee our ownership. As a company, we will also establish a legal framework to create industry standards and capture more market share as early as possible.

For the preparation phase on Earth,



We prepare the equipment we need, assess our needs, and purchase or develop our equipment accordingly. The operators are then thoroughly trained, allowing them to operate excavators and other machinery remotely with a high level of proficiency.

Afterward, a simulation laboratory will be set up on Earth, where operators and equipment will work as a team in simulated lunar-like conditions, to replicate the entire mining process. During this process, various tasks will be set up for operators to help them become comfortable working with the equipment. At the same time, performing several repetitive test tasks will help us to identify potential risks that operators may face during the mining process and to develop contingency plans to avoid or respond to these hazards promptly.[5]

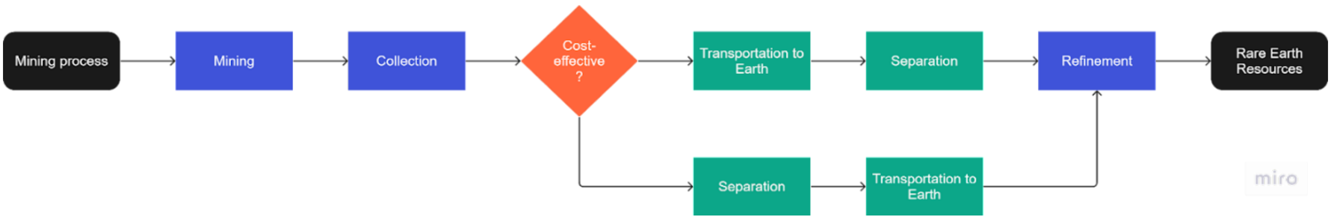
The entire prototype will be assessed in the following ways:

1. Ensure the simulation lab faithfully replicates lunar conditions. 2. Test mining equipment, including drills, excavators, and other machinery, to see how they perform under lunar conditions. 3. Assess the mining process' effectiveness. 4. Evaluate the mining process's safety.

We will then make modifications to the equipment, procedures, or simulation laboratory settings based on the results of testing and analysis as well as feedback from people, which means we will go back to the preparation phase on Earth. Because the cost of failure on the Moon far exceeds the cost of repeated simulations on Earth, we will repeat the process of testing, analysis, modification, and preparation until the prototype meets the requirements for a successful lunar mining process. The safety of human life is our primary concern throughout this project.

The team will initiate mining activities on the moon after the successful testing of the prototype in the simulation lab. The mining equipment will first be transported to the lunar surface, where we must ensure it lands properly. We will then send operators by spacecraft to an orbit around the moon, keeping them on board to remotely operate the equipment for mining, which will greatly help us to ensure the lives of the operators.

The steps of the mining process on the Moon are somewhat similar to the mining process on Earth. So when the operations and equipment are ready, we will proceed with mining as usual and then collect. But for the next steps, we will be faced with the question of whether to transport the rare metals back to Earth before separating the impurities or to separate on the Moon first and then transport the rare metals back to Earth.



On this issue, there are several influencing factors that our team believes need to be carefully evaluated to determine the most cost-effective option. The first is the cost of bringing the rare metals back to Earth, which will depend on factors such as the weight of the metals and how they are returned. If the cost of delivery is too expensive, separating them on the moon may be a better option. Second, the cost of the equipment used to separate the impurities will also have a significant influence. The cost of purchasing the equipment and maintaining it on the moon is difficult to estimate, which could significantly increase operating costs. Therefore, it would be more tractable to use the existing infrastructure to perform the separation on Earth. In addition, the complexity of the separation process is something we need to consider. As a mining company, we do not want to spend a lot of time and money developing a specific but not unique technology. This would not be worth it for us.

Due to the limitations of current technology, our team has not been able to provide an accurate prognosis so far. But we believe that as new technologies become available, all of these expenses will change considerably. Thus, a new assessment of the expenses must be made at that point.

After the rare earth metals are brought back to Earth, we go back to the original mining process on Earth, which means refining and using. And If everything goes well, we will have our new production line.

VI. Analysis of financial costs and potential benefits

The cost of developing and launching spacecraft and equipment for a moon mining mission would be high, but the potential rewards would be even higher. A lunar mission could cost between $20 and $30 billion, according to NASA estimates. The value of rare earth metals on the moon, on the other hand, could be as high as $100 billion. This implies that the rate of return on this investment could range between 70% and 80%, which is an appealing proposition for investors.[6]

It's essential to be aware that those estimates are primarily based on various assumptions and projections, and the real cost and advantages of a moon mining mission should range appreciably relying on several factors, which include the performance of the mining operation, the supply of professional personnel, the fee of launching and running the important equipment, and the marketplace call for uncommon earth metals.

The hit improvement of lunar mining should bring significant economic benefits, not just from the extraction and sale of rare earth resources but also from the creation of new industries and technologies. The improvement of lunar mining may also create new possibilities for studies and innovation, as scientists and engineers paint to resolve the numerous technical and logistical challenges of running. In addition to mining engineers and geologists, the operation would also require a crew of astronauts who're skilled to perform mining equipment and carry out numerous responsibilities associated with mining operations. Communication experts could additionally be had to preserve communique among the lunar mining operation and challenge manipulation on Earth. In addition, the development of lunar mining should have spillover results in different sectors of the economy, which includes the aerospace enterprise, which could benefit from the development of new space technologies and equipment. The establishment of a lunar mining industry could also create new jobs and opportunities for skilled workers in various fields, such as engineering, geology, and space exploration.

A successful lunar mining operation would be a significant step forward in space exploration, potentially paving the way for future missions to extract valuable resources from other celestial bodies in our solar system. The ability to mine resources on the moon could pave the way for new frontiers in space exploration, leading to more scientific discoveries and technological advancements. In conclusion, this is a project that achieves a balance of economic and social benefits and has the potential to have a long-term impact on humanity's space exploration.

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