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Feasibility research on mars colonization by 2060

Jay Hongfei Zhao

Valencia College, Orlando, 32811, USA

Anothersky576@gmail.com

Abstract. Exploring the immense cosmos is not just the fundamental survival urge for humans, but also the inescapable final aim of human civilization. Mars exploration will be the first step that human civilization takes to explore this universe because, for one thing, Mars and Earth are the two close planets; for another, Mars is located in the habitable zone in the solar system. This research is aimed to analyze the main problems of human migration to Mars with the current state of technology in a timeframe of a few decades. The research is conducted based on three basic factors for humans to live: water, shelter, and food, with the addition of law to support a colony. The result indicates more research to be conducted due to many unknown factors that will happen in a new environment.

Keywords: Mars Migration, Life Support on Mars, Martian Soil, Water on Mars, Mars.

1. Introduction

About three billion years ago, Mars had a period when it is warm and moist, similar to the current stage of Earth. During that time, Mars had a thick atmosphere and running water on the surface. Many scientists believe Mars was once a planet where life could have a chance to breed. In the past decade of spaceflight, humans have conducted more than 48 probes on Mars to gather a large amount of data [1]. Mars has become the most well-understood planet besides Earth and humans setting foot on Mars is also a very hot topic in recent years. SpaceX's president, Elon Musk envisions that there will be one million humans living on Mars by the year 2060. Bringing one million people in a few decades with the current technology is the first step and the easiest step. The main challenges come down to the current state of progress on interplanetary migration life support technologies and the sustainability of the technologies to support a large colony since the life support technology will maintain the most basic human survival factors: water, food, and shelter. This paper describes the major difficulties that Mars immigrants will face in a few decades from the perspectives of water, shelter, food, and law, thereby providing a clear clue for scientists and civilian companies about what they need to break through.

2. Water resource utilization and storage for Mars colonization

Today, what scientists have observed for the past decade shows that Mars is a very dry planet. Water being one of the most important elements in life becomes a very scarce resource on Mars. The majority of water on Mars is ice-formed and appears to be on the pole or lies under the surface, while a small amount of water is in the form of gas and exists in the thin atmosphere [2].

2.1. Water resource utilization on Mars

In July 2018, according to a report, a large saltwater lake was discovered by European Space Agency's Mars-orbiting spacecraft named Mars Express. The saltwater lake has a depth of 1.5km in a 200km-wide area [3]. The lake is located under the polar ice cap which means humans will need to conduct further experiments in order to dig the ice cap safely. The high sodium content acts as a barrier that blocks the water molecules from gathering up together and lowers the freezing point of water, thus keeping water from freezing after billions of years. With the evolution of technology, the water from the ice cap can be melted into useful water for the first group of human pioneers and the potential use of salt water from the lake can be filtered by a filter system similar to the system in a modern-day aircraft carrier.

2.2. Water resource storage problem on Mars

According to Musk's word of one million people on Mars, supporting a population that is roughly the size of the state of Delaware will need about 175 million gallons of liquid water for consumers per day as an average person uses roughly 100 to 175 gallons of water daily not including other operations [4,5]. If every household would have a filter system that filters 90% of water just like the system on the International Space Station [6], an estimated 10-17.5 million gallons of water would be needed to flow through the entire colony every day.

Due to the thin atmosphere, storing water for the colony will become a significant challenge. Mars's atmospheric pressure is less than 1% of Earth's [7]. Low atmospheric pressure develops a big temperature fluctuation between day and night. During the daytime, the temperature can be 20 degrees Celsius near the equator in the summer. At night, the temperature can drop from 20 degrees Celsius to negative 73 degrees Celsius [8], which means the water in storage will be frozen if there is no special treatment done to it. Although water freezes below 0 degrees Celsius under normal circumstances, during water transport and water storage, human or unmanned vehicles can always put a high amount of sodium in fresh or unfiltered water to decrease the freezing point.

3. Shelter and raw material selection for Mars immigrants

Sheltering is one of the most important factors of living. The base that the first human pioneer will use is a temporary base that will be used for a period of transition. Due to the heat imbalances on Mars [9], there will be frequent dust storms occurring every once in a while. A recent record of a dust storm on Mars in January of 2022 has a size that is twice of the United States covering up the southern hemisphere [10]. A dust storm like this can potentially last up to several months and is most likely to cause significant damage to the surface device. As a result, the long-term shelter for the pioneers must be built underground or in protection.

To from a long-term living standpoint, the underground base is not a good option for persistent living. It is necessary for immigrants to feel the day and night changes of the planet, which is crucial to the physical and mental health of the human body. NASA launched a 3D printing Martian base competition almost a decade ago to solicit proposals for the construction of base plans from all over the world. A few years later, the company AI-SpaceFactory was announced to be the winner of the competition.

AI-SpaceFactory's Marsha design implements a robotic 3D printing arm and robots that uses a newly developed material that is specifically for Martian 3D printing called basalt fiber-reinforced polylactic acid. Basalt fiber-reinforced polylactic acid is a thermoplastic that is not only recyclable but also renewable. In addition, it possesses one of the lowest coefficients of thermal expansion among plastics which is crucial for Marsha's outer layer to withstand the constant temperature fluctuation on Mars.

As common knowledge, materials will expand in heat and shrink in cold. Stress will eventually cause any substance that can not expand or shrink to break down. Marsha's double-layer design will overcome this problem.

Marsha's outer shell is a pressure vessel that is attached to a sliding bearing while the anchors and clamps keep the flange from uplifting for the inner shell. The inner shell is separated from the outer shell entirely to create a light, airy, and exceptionally space-optimized interior. The open space between these two shells acts as a light well that allows natural light and circadian lighting to connect to every level. The unique cylindrical shape of the shell can be used as a support for the stairs to be built from floor to floor (Fig. 1 and Fig. 2).

Figure 1. Marsha Interior [11].

Figure 2. Marsha Cutaway [12].

The cylindrical design not only offers the highest ratios of the usable floor area to the surface area and the usable floor area to the volume and diameter, but it also helps create very effective pressure vessels. Reducing diameter lowers structural stresses, especially at a base where uplift pressures would require anchoring into the ground. Meanwhile, reducing the surface area and volume can also minimize material use and energy burdens on mechanical systems. They do not create unusable overhead volume or unusable peripheral floor space, in contrast to domes. Therefore, decreasing the width area and increasing space vertically is the most straightforward strategy to decrease structural loading and increase usable space [11].

4. Food soil cultivation on Mars

The concept of growing plants is based on three points: carbon dioxide, light sources, and soil. Mars, a planet named after the Roman God of War, is a planet with a reddish color due to the oxidation of the high iron-concentrated soil. The soil on Mars is not ideal for Earth plants to grow due to the lack of nutrients. The composition of soil on Mars contains 98 percent mineral matter with only 2 percent water compared to Earth's 45 percent mineral matter and a whopping 50 percent of water in addition to 5 percent of organic matter that plays a critical function in plant growth [13].

Despite the fact that the soil on Mars is unsuitable for Earth's planet to survive, recent research done by a few "Martian Farmers" has proven the possibility that certain planets may be able to survive in Martian soil. Throughout the course of eight weeks, tomatoes, yellow bell peppers, green okra, squash, and basil will be grown in two types of soil, simulated Martian soil and Earth's potting soil. Squash and sweet potatoes were added later to extend the experiment. To learn how seeds germinate in Martian soil, another experiment was conducted where carrot, spinach, onion, hot pepper, tomato, and squash were added to both soils. The simulated Martian soil imitated the conditions on Mars. Every Monday, the plants would receive 100 milliliters of water. Every week, the plant height was recorded to monitor the changes in growth.

During the experiment, Martian soil caused the plant to turn less green and more yellow. Due to that, the same type of plant was used in another group of experiments with NPK (Phosphorus, Nitrogen, and Potassium) fertilizer being added in both simulated Martian soil and Earth's potting soil.

At the end of the experiment, the average height of the majority of plants that were planted in simulated Martian soil was a little bit shorter than that in Earth's potting soil. While NPK fertilizer used in simulated Martian soil did help plants to retain a healthier color and achieve a taller average growth height, it did not work with plants such as tomatoes and basil. The tomato was the only plant that was able to produce fruit without having NPK fertilizer in simulated Martian soil.

The experiment concluded that on average, some plants, such as succulents and cacti, perform better in the Martian soil than others, including food plants, which do not grow nearly as well as their nonedible counterpart; some plants in the soil reacted like those in Earth potting soil when the experimenters applied NPK fertilizer to the simulated Martian soil. However, more tests must be conducted due to the diverse condition and different environments on Mars [14].

5. The Martian law system

As more and more people arrive on Mars for settlement, there will be people from all nations and ethnicities. Despite the fact that they are chosen elites, the difficulty that this enormous Martian metropolis will face is how to construct a flawless Martian society that can provide a healthy environment for future Martian immigrants or even Martian civilization.

In terms of the construction of a Martian society, there are many dimensions to consider. Back in the Age of Discovery and colonization in the 1500s when several countries set sail to discover new routes and search for civilization, the main reason that the first few colonization failed is that members from different expeditions attacked each other for land and resources which resulted in infighting. Martian immigrants are likewise confronted with difficult societal issues.

Antarctica is in a similar scenario to the impending Martian settlement. In December 1959, twelve countries signed the Antarctic Treaty and it expanded to fifty-four as of 2022. The treaty aims to make Antarctica a place of peace rather than a place full of international conflicts. Besides, the treaty also limits the government on the world's only continent without a resident population [15]. The Outer Space Treaty, which was signed by a number of nations in 1966, also stated that no nation may assert sovereignty over any territory outside of planet Earth, including the moon and Mars [16].

The Antarctica Treaty and the Outer Space Treaty have both been poorly enforced by nations. And in these places, military action always takes priority first. For Mars, which is more than a million miles away from Earth, the question of whether particular human laws or systems will work or not still remains. It is known that disagreement stems from the loss of benefits. For Mars, limited resources will undoubtedly be a focal point for future resource competition. Before the mass migration, Martian settlers should develop a good economic structure to minimize resource disputes. For instance, the efficient use of local resources, a new trade system, and perhaps even the introduction of a new type of currency system. People on Mars will then require a governance structure, which will consist of selecting individuals or groups to govern Martian people.

During ReCode's Code Conference, SpaceX president Elon Musk proposed a governing system where sixty percent of agreement from people is needed to pass a law, and only forty percent is needed to remove it. He thinks that direct democracy, rather than a representative government, is more likely to exist on Mars because compared to representative democracy, the potential corruption of direct democracy will be greatly reduced [17].

Different solutions are needed in various settings and geographical locations. It is still worthwhile to test whether this system will work on Mars because these systems are merely designs based on Earth's social environment. On Earth, for example, humans practice humanitarianism where life is saved at all costs. It is a different situation on Mars because saving another person could potentially cost more deaths and the usage of limited resources and supplies can have an overall negative impact.

6. Conclusion

Exploration of space has a similar purpose to the Age of Discovery in the old days, that is, going to a place of the unknown and trying to find a place for a better living. Space exploration, as it is known to all, is prohibitively expensive. To merely send a man to the moon, the United States Apollo moon landing program cost tens of billions of dollars back in the 60s which is estimated to be billions of dollars now, not to mention how much it would cost if construction activities were needed.

Timewise, mass colonization is not optimistic at present because human beings have too little experience and technology to support life in a completely different environment. Although various plans and experimental studies are being carried out all over the world, migration is still too early for a planet that humans have not yet set foot on. There are still many problems people need to solve, such as the storage of water, the selection of shelter materials, the cultivation of food, and the construction of the law system mentioned in this paper. These problems will be the most critical ones for Martian migration. In fact, the conditions that allow life to survive are far more complicated than the basic factors of life. Although modern technology cannot support a large group of humans on Mars, it can always support a group of scientists to conduct experiments on Mars before the large group arrives in the future.

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