Current Status, Challenges and Prospects of Human Survival on Mars: A Literature Review

Zhihang Zheng
Affiliated High School of Fujian Normal University organization Fuzhou, China
zhengzhihang071206@gmail.com

Abstract. This literature review provides a comprehensive examination of the current understanding of human survival on Mars, focusing on key challenges and potential solutions. The review begins by discussing the harsh Martian environment, which includes extreme temperatures, low atmospheric pressure, and high levels of radiation, all of which pose significant obstacles for human habitation. It further explores the technological advancements required to establish a sustainable human presence, such as life support systems, energy generation, and efficient transportation methods. Physiologically, humans would face challenges like muscle atrophy, bone density loss, and the effects of prolonged radiation exposure, which would require innovative countermeasures. Additionally, psychological challenges, including isolation and the potential for mental health issues, would need to be addressed through robust support systems and strategies. The review also considers the social and ethical implications of sending humans to Mars, such as the potential for inequality and the risk of contamination. By integrating research from various scientific fields, this review highlights the complex nature of Mars colonization and identifies critical areas for future research and technological development.

Keywords: Human survival on Mars, Martian environment, technological requirements.

1. Introduction

The idea of human colonization of Mars has captured the imagination of scientists, engineers, and the general public alike. Mars, often referred to as the “Red Planet,” is the most Earth - like planet in our solar system. It has a relatively accessible distance (compared to other planets), and its exploration could potentially provide answers to fundamental questions about the origin of life, the evolution of planets, and the future of humanity. However, the journey to and survival on Mars presents numerous and complex challenges.

2. The Martian Environment

2.1. The Difference from Earth

"The atmosphere on Mars is very different from the atmosphere on Earth." Wei Yong, a researcher at the Institute of Geology and Geophysics of the Chinese Academy of Sciences, said that the Earth's atmospheric composition is mainly nitrogen and oxygen, while the Martian atmosphere accounts for 96% of carbon dioxide, argon and nitrogen accounted for 1.9% each, and other components are mainly oxygen, carbon monoxide, water and methane. The average atmospheric pressure on the surface of Mars is 600 pascals, which is only 0.6 percent of the atmospheric pressure on Earth." The total mass of the Martian atmosphere is about 0.5% of the total mass of the Earth's atmosphere, and its gravity is only 40% of the gravity at the Earth's surface. "A planet has to have enough surface gravity to pull in air molecules and retain an atmosphere." Said Shi Jiankui, a researcher at the Space Science and Application Center of the Chinese Academy of Sciences. As a result, Mars has a very thin atmosphere compared to Earth. At the same time, the temperature of Mars fluctuates obviously day and night, the temperature of the equator can reach 21℃, and it will suddenly drop to -73℃ at night. But similar to the environment on Earth, there are various levels of dust storms on Mars. Mars has no liquid water, is very dry, and moderate dust storms occur several times a year, covering millions of square kilometers and lasting several weeks. A superstrong dust storm also occurs about every five to six years, covering the entire planet. Such super-strong dust storms have been observed many times since the 20th century, with the most recent being in 2007. Wind speeds on Mars are much weaker than on Earth, and its atmosphere is less than 1% as dense as Earth's, so a thin atmosphere at the same wind speed is much less destructive than a dense atmosphere. For example, a puff of air on Earth can make a piece of A4 paper float, while the thin air on Mars may require high wind speeds from an electric fan to lift the paper. A solar day on Earth is 23 hours and 56 minutes, and a solar day on Mars is 24 hours and 37 minutes. In other words, a day on Mars is 41 minutes longer than a day on Earth. One revolution around the sun equals about two years on Earth, or 687 days in a Martian year [1].

2.2. Space Radiation

Without oxygen, humans can use the oxygen supply system they carry with them; The average temperature is low, and the temperature difference between morning and night is large, which can be adjusted by humans through spacesuits. However, in order to truly survive on Mars, its radiation must also be considered. 0 "In the Martian, there is relatively little description of Martian radiation. In fact, the radiation on Mars is very strong." Said Zhang Xiaoxin, director of the National Space Weather Monitoring and Warning Center. NASA recently said it wants to send people to Mars by around 2035, just as it sent astronauts to the moon. "Mars, unlike Earth, does not have a global dipole magnetic field, only weak rock remanence." Wei Yong said, "If an astronaut walks on the surface of Mars with a compass, the direction of the pointer will change greatly at any time. So, hoping pigeons, bats and other animals that rely on magnetic fields for navigation would be 'unable to find north' if they got to Mars." In addition, the Earth's dipole magnetic field has a very important role in preventing the intrusion of high-energy charged particles in the universe. "This is because charged particles are deflected when they encounter magnetic fields." Wei Yong said, "The Earth's dipole magnetic field is like a protective shield, protecting the biosphere, so that humans can survive on the Earth for a long time." Without that shield, Mars would always be exposed to large doses of radiation." In addition, Mars' atmosphere is much thinner than Earth's, so its own weakening effect on high-energy particles and space radiation is limited. In such an environment, people must live in special radiation-proof camps and wear protective clothing when they go out. Not only that, on the way to Mars, humans will also face low doses of long-lived galactic cosmic rays. These rays have large energy, strong penetration, and are difficult to protect, and the ordinary spaceship shell can basically not stop them, even if it is 30 cm thick aluminum plate, the protective effect is extremely limited, seriously threatening the health of the astronauts. Therefore, it would be difficult for people to survive on Mars [1].

3. Technological Requirements for Human Survival on Mars

3.1. Transportation

The journey to Mars is a major technological hurdle. Current spacecraft propulsion systems are relatively slow, with typical transit times of several months to over a year. New propulsion technologies, such as nuclear - thermal or plasma - based propulsion, are being explored to reduce travel times. Additionally, spacecraft needs to be designed to withstand the rigors of the long - duration journey, including exposure to radiation and microgravity.

Landing on Mars is also a complex process. The thin atmosphere requires specialized landing systems, such as parachutes, retro rockets, and airbags. Future landers may also need to be able to autonomously select suitable landing sites based on real - time data.

3.2. Habitat Construction

Basalt is a kind of rock formed by the cooling and solidification of magma from volcanic eruptions. It is widely used in paving stones because of its hardness and corrosion resistance. However, the researchers found that when it is made into basalt fibers, the potential is even greater. Ma Peng Cheng and his team continue to explore the distribution of basalt, melt fiber forming technology and infiltrating agent formulation, providing theoretical and technical support for the study of Martian soil fiber. They found that the simulated Martian soil could be completely melted at 1360 ° C, and high-strength Martian soil fibers were formed by wire-drawing technology. These fibers are not only twice as strong as steel fibers of the same diameter, but also have corrosion resistance and extreme temperature resistance, which is suitable for Mars base construction. The combination of Martian soil and basalt fibers can produce high-strength composite materials. In addition, basalt fiber has also been developed as a conductive material and has shown promising applications in the field of gas purification and has developed high efficiency air filtration materials with filtration efficiency of more than 99.99%. With the deepening of research, the application field of basalt fiber continues to expand, showing huge market potential and future development space [2].

3.3. Life Support Systems

A reliable life support system is essential for human survival on Mars. This includes systems for providing breathable air, water purification, waste management, and food production. For air, a system will need to generate oxygen from Martian resources (such as by electrolyzing water or extracting oxygen from carbon dioxide). Carbon dioxide removal and control of other trace gases will also be necessary. Water purification systems will need to be highly efficient to recycle water from various sources, including urine, sweat, and condensate. Waste management will

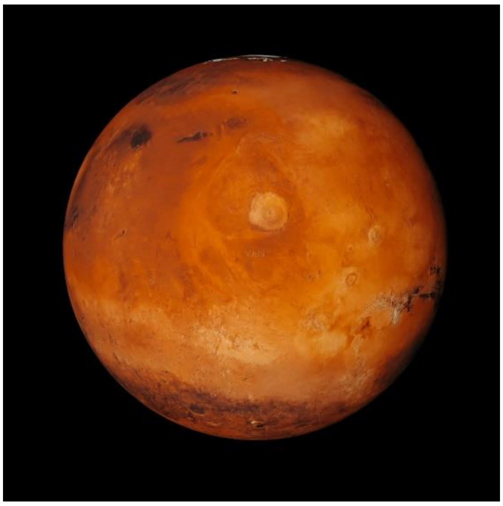

Fig. 1 Mars

involve not only the disposal of solid and liquid waste but also the recycling of valuable resources from waste.

Food production on Mars is a complex issue. While hydroponics and aeroponics are promising methods for growing plants in a controlled environment, adapting plants to the Martian conditions (such as low - gravity, high - carbon - dioxide atmosphere, and different light spectra) will require extensive research.

3.4. Resource Generation

MOXIE is a cuboid device with an exterior size of 23.9cm×23.9cm×30.9cm and a mass of 18kg (see left in Fig. 1). Its interior is composed of scroll pump compressed gas device, solid oxide electrolysis device, gas filtration, flow heat and circuit control system (see Fig. 1 right). MOXIE can collect Martian CO_2, the Martian atmosphere is filtered and compressed, and then injected into the solid oxide electrolytic reaction unit, the CO_2 is electrolyzed in the electrolytic unit, and the anode outlet exhausts O_2, and the cathode outlet exhausts CO. The solid oxide electrolytic reaction device is mainly composed of a heater and a solid oxide electrolytic pool pile (as shown in Fig. 4). The heater can heat the electric pile to 800℃, and CO_2 is electrolytic reaction at this temperature. The entire MOXIE device consists of 10 single electrolytic cells connected to form the top reactor (T) and the bottom reactor (B). The active area of the single electrolytic cell is about 21cm2, and each reactor is formed by five electrolytic cells in series (Fig. 2). The whole stack is 10cm long, 5cm wide, 3cm high, and has a mass of 770g. The external structure of the reactor, the internal connection of the reactor and the gas flow mode are shown in Fig. 2. In order to prevent gas leakage in the reactor and gas collusion between the electrolytic cell, the electrolytic cell sheet and the chrome-iron yttrium (CFY) alloy connector are sealed with special glass materials. Developed by Plansee of Austria, CFY is composed of 95% Cr, 5% Fe and trace Y. The thermal expansion coefficient of the CFY alloy matches perfectly with scandium oxide stable zirconia (ScSZ) and has good electrical conductivity and oxidation resistance. The glass ceiling material is microcrystalline glass, produced by Schott Company in Germany, which can work stably in an environment of -55 ~ 800 ° C and can withstand multiple hot and cold cycles. MOXIE will be subjected to harsh environments during its journey to Mars and its surface. As shown in Fig. 3, before landing on Mars, MOXIE will need to undergo a series of high-intensity environmental tests, including mechanical compression test, vibration test, shock test and thermal cycle test [3].

4. Physiological and Psychological Challenges

4.1. Physiological Adaptations

The space environment is very different from the ground environment to which humans have adapted. The harsh and extreme space environment poses a great challenge to the smooth development of manned space missions. The most obvious is the negative impact on the human body caused by the low gravity environment in space (refers to weightlessness and microgravity, that is, the acceleration of gravity is greater than or equal to zero but less than the surface gravity speed). Including muscle atrophy, poor balance ability, weakened cardiovascular function and skeletal osteoporosis [4], resulting in a decline in human aerobic exercise capacity, muscle strength and other problems, seriously affecting the safety, health and work efficiency of astronauts. In the microgravity environment, not only the physiological function is affected, but also the movement pattern of the limbs will change greatly. Take the Apollo lunar landing mission as an example, the gait and step length of astronauts walking on the lunar surface are very different from those in the surface gravity environment [5-7]. The most direct way to study the influence of low gravity on human movement function and mode is to conduct experiments in space low gravity environment, but this is not practical under the existing technological conditions. Besides high cost, there are difficulties in the use of data acquisition instruments and the number of experimental samples [8]. Since the Apollo program era, to ensure the safety and health of astronauts in the space environment, to ensure the successful completion of manned space missions, domestic and foreign space agencies have carried out research and attempts to simulate the low-gravity environment on the ground and conduct astronaut training and found out a series of methods to simulate weightlessness training in practice. As shown in Fig. 5, parabolic flight [9], neutral buoyancy pool, virtual reality technology, air float platform technology and suspension gravity compensation system.

4.2. Psychological Well - being

When humans set foot on the mysterious and challenging land of Mars, the psychological test is no less difficult than the physical adaptation.

First, there was a haze of extreme loneliness. Mars is hundreds of millions of kilometers away from Earth, and communication signals take ten minutes or more each way, which means that communication between astronauts and family and friends becomes slow and difficult. The daily joys and sorrows cannot be shared in time, the important festivals cannot be accompanied, the yearning is constantly fermenting in the long wait, it is easy to fall into deep loneliness, and depression will also breed. They may shed silent tears in the silent Martian night in the direction of the Earth, gradually lose enthusiasm for life, and even question whether they have made the right choice far from home.

The harsh and unfamiliar natural environment of Mars constantly stimulates the psychological defense. Violent sandstorms can instantly obscure the sight, damage equipment, and make people in a moment of panic, as if the next second will be swallowed ruthlessly; Ubiquitous cosmic radiation, like a hidden killer, even in heavy protective clothing, psychological will still be invisible but harmful threat of worry, in the long run, anxiety, insomnia become the norm, post-traumatic stress disorder is also very easy to appear.

Moreover, the small monotonous living space and the same routine are suffocating. The limited range of activities in the base and the repetitive task process day after day numb the senses, and the passion for exploration is exhausted, as if it is trapped in a dead cycle of time, and the sense of depression and boredom comes surging.

Faced with these intractable problems, a series of effective solutions need to be implemented. The virtual reality experience room is carefully built in the base, and with the help of advanced technology, astronauts can be immersed in the bustling cities and beautiful mountains of the earth at any time, and feel the warmth of home and comfort the heart of homesickness. Set up music studio, handicraft workshop, spare time to indulge in creativity, with art to express inner emotions, inject vitality into boring life.

Establish a sound and sensitive emergency psychological intervention system, with the help of wearable devices to monitor psychological indicators in real time, once abnormal fluctuations, professional psychologists quickly through remote or on-site intervention, the use of cognitive behavioral therapy, relaxation training and other professional means to help astronauts disperse the haze and rebuild confidence.

Team cohesion is the key to psychological support. Regularly organize outdoor exploration, sample collection competitions in relatively safe areas of Mars, or organize knowledge questions and answers, covering Mars knowledge, Earth culture, etc., so that astronauts can enhance friendship in cooperation and competition, rely on each other, gather into an indestructible whole, and work together to overcome various psychological difficulties in Mars life, and forge ahead toward the future of human interstellar exploration.

Fig. 2 Red Planet

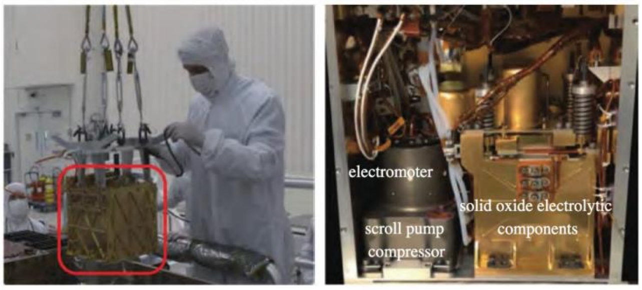

Fig. 3 MOXIE Device outline and structural component drawing [3].

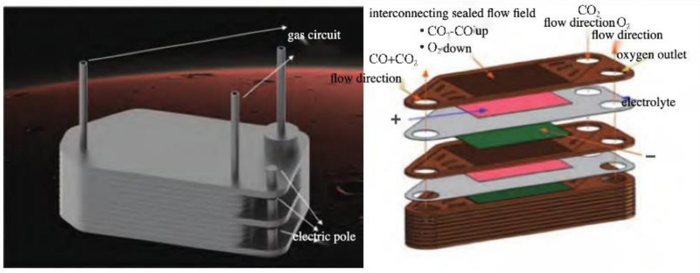

Fig. 4 Solid oxide electrolytic cell reactor exterior and internal structure diagram [3].

resources, the expansion of the colony, and the resolution of disputes. Will the laws of Earth apply, or will a new legal system be created specifically for Mars?

The division of labor within the colony will also be an important consideration. There will be a need for a diverse range of skills, from scientists and engineers to farmers and medical personnel. Ensuring fair distribution of work and resources and promoting social harmony will be challenging.

4.3. Ethical Considerations

There are several ethical issues associated with human survival on Mars [10]. One of the main concerns is the potential for contamination. Earth-based organisms could contaminate the Martian environment, which could have unforeseen consequences for scientific research and the search for native Martian life. On the other hand, Martian organisms (if they exist) could also pose a threat to human health if they are accidentally introduced to human habitats.

Another ethical consideration is the long - term impact on humanity. Will the focus on Mars colonization divert resources from solving problems on Earth, such as poverty, environmental degradation, and global health issues? And

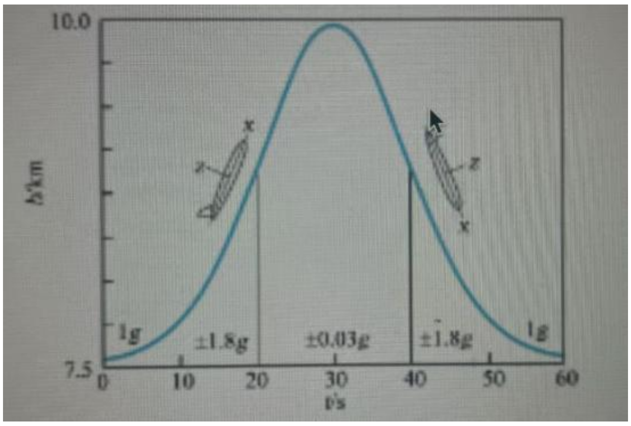

Fig. 5 Parabolic flight [9].

What are the implications for future generations if a significant portion of humanity migrates to Mars?

5. Conclusion

The concept of human survival on Mars is a complex and multi-faceted topic. While significant progress has been made in understanding the Martian environment and developing the necessary technologies, there are still many challenges to overcome. Physiological and psychological challenges, as well as social and ethical implications, need to be carefully considered. Future research should focus on improving transportation systems, developing more efficient life support and habitat construction technologies, understanding the long-term effects of the Martian environment on humans, and addressing the social and ethical issues associated with Mars colonization. By continuing to explore these areas, humanity may one day be able to establish a sustainable presence on Mars.

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