

Physiological and Psychological Aspects of Sending Humans to Mars

Challenges and Recommendations

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Abstract

The body is an extraordinary and complicated system that automatically detects, and responds to, dramatic environmental changes around it, particularly in an environment of weightlessness. The entire body is involved in the complex and rapid response to micro- or zero gravity, and space science is just beginning to form a picture of what is happening inside the body under these conditions. When an astronaut goes into space, as will be the case during an eventual mission to Mars, his or her body will immediately begin to experience a multitude of changes, causing the astronaut to feel and look slightly different. The crew would succumb to massive bone and muscle loss as a direct result of long-term exposure to micro- or zero gravity, and would suffer cell damage from ionizing cosmic radiation, potential permanent vision problems, and psychological and sociological deterioration due to isolation. Nonetheless, past space flight experiences from crews in the United States and the former Soviet Union have demonstrated that humans can survive space flights of several months, or even up to a year in duration. This study identifies the psychological and physiological aspects of a manned mission to Mars and will recommend countermeasures and prevention strategies designed to combat many of the problems associated with long-term exposures in space. The International Space Station (ISS), moreover, has an enormously vital role in assessing the health dangers of sending humans to Mars. Thus, a recommendation to place a crew on the ISS to simulate a flight to Mars is addressed.

Introduction

Prior to the twentieth century, there was little opportunity to explore Mars except via astronomical observations and science fiction [1]. The last few decades, however, have brought forth many significant achievements in space exploration, transforming the human thirst for sending humans to Mars into a technologically achievable goal. Recent breakthroughs in space technology, space medicine, and cooperation among international space agencies, have contributed significantly toward transforming this fiction into a reality. There are, however, substantial differences between low-earth orbit operations and exploring interplanetary space. A manned mission to Mars will place humans in a remorseless environment that will not tolerate human error or technical failure. The challenges, to name a few, will include massive bone and muscle loss as a direct result of long-term exposure to micro- or zero gravity, and cell damage from ionizing cosmic radiation, potential permanent vision problems, and psychological and sociological deterioration due to isolation. Moreover, because the distance between Mars and Earth would require a 2-3 year long round trip [2] [18], the massive undertaking of developing nutritional and medical strategies would be required in order for the mission to Mars to succeed.

1. Physiological Aspects of Space Travel

1.1 Radiation

Earth's magnetic field protects astronauts in low Earth orbit from harmful radiation. Although these astronauts are more exposed to radiation than humans on the ground, they are still protected by the Earth's magnetosphere [2]. A manned mission to Mars, however, will introduce the spacecraft and its crew to an environment outside of this protective shield. During the Apollo program, for instance, astronauts on the moon reported seeing flashes of light, and experienced painful cataracts; these flashes were due to radiation from cosmic rays interacting with matter, and depositing its energy directly into the eyes of the astronaut [3]. It is important to note, however, that the Apollo missions were comparatively short and are not comparable to a 2-3 year trip to Mars and back. The crew enroute to Mars will be outside of Earth's magnetosphere and thus will be at risk from radiation capable of critically damaging the spacecraft; absorption of fatal radiation doses from gamma ray bursts, and/or potential damage to DNA at the cellular level (which may eventually lead to cancer).

The first recommendation for a manned mission to Mars, therefore, requires a spacecraft built with a heavily shielded area that the astronauts can use to protect themselves from life threatening radiation events. In the past decade, concept engineers have moved on from traditional aluminum shields and envision any spacecraft traveling to Mars with a "storm shelter" made of better shielding materials. Some ideas include the use of a magnetic field to create a protective shell around the spacecraft, and use of low-density materials, such as water tanks (which would be needed anyway for a long-term mission), to surround the crew's habitat [4]. Countermeasures other than better shielding would also play a vital role in protecting the crew from harmful radiation; this would include a diet plan containing antioxidants such as vitamins E, C, and A, beta-carotene, and selenium, which have been shown to minimize damage to the skin caused by radiation [5].

1.2 The Cardiovascular System in Space

Although the cardiovascular and pulmonary systems (including the heart, lungs, and blood vessels) adapt well in space, they function differently in micro- or zero gravity than on Earth. An astronaut's cardiovascular system begins to adapt to weightlessness as soon as the blood and other body fluids shift from their lower extremities (feet, legs, and lower trunk) to the upper body, chest, and head. The shifting of these fluids causes the heart to enlarge so that it is capable of handling the increase of blood flow. Although the astronaut's body still contains the same total fluid volume at this point, a higher proportion of fluids have accumulated in the upper body (resulting in what is commonly referred to as puffy face and chicken leg syndrome) [9]. The brain and other systems in his/her body then interpret this increase in blood and fluids as a "flood" in the upper body. The astronaut's body reacts to correct this "flood" by getting rid of some of the "excess" body fluid (for

example, astronauts become less thirsty and the kidneys increase the output of urine) [6]. These actions decrease the overall quantity of fluids and electrolytes in the body, which leads to a reduction in total circulating blood volume. Once the fluid levels have decreased and the heart no longer needs to work against gravity, the heart shrinks in size, which can degrade performance in an astronaut's duties. Upon returning to normal gravity, the astronaut will experience postflight orthostatic intolerance. Since the astronaut's cardiovascular system adapted to weightlessness, it will initially be unable to function efficiently upon return to gravity. Nearly 63% [7] of astronauts returning from space experience postflight orthostatic intolerance. Symptoms of post-flight orthostatic intolerance include lightheadedness, headaches, fatigue, altered vision, weakness, sweating, anxiety, and heart palpitations as a result of the heart racing to compensate for falling blood pressure [7]. Logically, an astronaut experiencing any combination of these symptoms when he/she arrives on Mars will initially not be able to function (Figure 1).



Figure 1: An astronaut experiencing postflight orthostatic intolerance has difficulty walking on Earth (Photo from NASA)

The bigger question, however, is whether or not the crew, after a 6-month journey in deep space, would be able to function on Mars, which has 62% less gravity than Earth [8]. When the crew arrives on Mars, they would hypothetically be stronger compared to an astronaut returning to Earth's gravity after a mission of similar length. Recent studies of astronauts on long-term missions in space,

however, suggests a Mars bound flight with micro-gravity or zero-gravity for as many as 6 months would almost certainly cause incapacitation of the astronauts [18]. Astronauts immediately arriving on Mars would have trouble walking, suffer fatigue, and be in real danger of bone fracture and intermittent loss of consciousness. Moreover, according to NASA, six months in zero gravity (which is the time it will take to get to Mars) will take the astronaut 2 years of recovery time. Therefore, a mission profile which allows only 30-90 days on the surface of Mars would not give the crew enough time to recover from the 6 months in zero-gravity [8].

Today, there are several countermeasures and prevention strategies implemented in the astronaut corps specifically designed to combat postflight orthostatic intolerance and cardiovascular deconditioning [5]. Prior to spaceflight and throughout the journey, it is recommended that astronauts take part in vigorous aerobic and strength training exercises to improve endurance, increase blood volume, and maintain or increase heart mass. Additionally, medications like Erythropoietin (commonly used in dialysis for cancer patients) and fludrocortisones (commonly used to treat orthostatic hypotension) can increase red cell mass and blood volume. More importantly, after landing on Mars, astronauts must be allowed to gradually adapt to gravity to minimize postflight orthostatic intolerance. Likewise, the use of G- suits after landing will improve orthostatic tolerance, while a spacecraft designed with artificial gravity (intermittently, at a minimum) should theoretically load the vessels of the lower extremities to help minimize orthostatic intolerance [5].

1.3 The Neuro-Sensory System in Space

The most striking of all of the physiological changes astronauts experience are the changes in the neurovestibular system, which is the part of the nervous system largely responsible for balance mechanisms [6]. Weightlessness during a round trip to Mars will affect an astronaut's neurovestibular system. His or her perception of body orientation, point of reference, and equilibrium will be severely altered during the trip to Mars. As a result, astronauts will experience severe motion sickness symptoms that include disorientation, dizziness, depressed appetite, vomiting, and, in severe cases, extreme nausea [7]. This happens simply in part because weightlessness affects the otolith organs and the semicircular canals, both of which are in the inner ear. Our awareness and perception of our body's orientation on Earth is attributed to the detection of gravity by the otolith organs and the detection of head rotational movements by the semicircular canals. In weightlessness, these organs have trouble computing the body orientation relative to gravity, and the resulting signals no longer correspond with the visual and other sensory signals sent to the brain. In other words, an astronaut's brain has no concept of what is "up" or "down" [6]. Although not as severe as motion sickness, other effects on the neuro-sensory system will include diminished sensitivity to taste and smell, difficulty in hand-eye coordination and pointing at or concentrating on a certain object, and massive hearing stress due to loud life support equipment

inside the spacecraft. After a few weeks in weightlessness, however, the crew will begin to adapt. They will learn to propel themselves around by pushing off the overhead, deck, and bulkhead, and they will learn to "fly" through the spacecraft's cabin. In an effort to reinterpret the meaning of the otolith signals, and to provide some sort of a "down" reference, the interior of the spacecraft should have equipment and lettering positioned in the same direction.

Historically, motion sickness in space has not been a major problem. Nonetheless, the key to minimizing motion sickness and other effects to the vestibular system is prevention. Astronauts selected for the Mars mission must be those who can adapt to weightlessness easily and have no history of damage to the neurovestibular system. In the event of severe cases, medications such as promethazine and scopolamine are extremely effective in helping with motion sickness and thus recommended for a trip to Mars [5]. Other negligible measures to counter the effects on vestibular function are to add additional spices and condiments to add taste to meals, and to ensure that astronauts minimize excessive head movements early into the flight to Mars.

1.4 The Musculo-Skeletal System in Space

The human body has about 700 muscles [6]. Many of these muscles operate as cables that pull on bones to make motion possible. Their function is contraction - that is, they all work by shortening the angle between two bones. The force of gravity on the Earth's surface has shaped the structural design of nearly all life; our bodies look and function the way they do partly because of the continuous pull of this ever-present gravitational force on all of our parts. When we don't use certain muscles, however, they can go into "hibernation" mode [6]. In a weightless environment, where an astronaut does not use his or her muscles for a period of time, the muscles themselves begin to waste away, or atrophy. The long-term result on the astronaut's load-bearing tissues will be significant reduction of bone and muscle. Thus, muscle atrophy will cause problems for astronauts on a mission to Mars. For example, research done on rats in space discovered that being in microgravity for two weeks had converted a large portion of their muscle fibers from Type I to Type II [6]. This is due to the fact that, while in a weightless environment, the rats no longer needed their legs to balance and control their bodies against the force of gravity (the rats just floated around from one location to another). As a result, their muscles essentially began to change during space flight. Likewise, we must assume that the crew arriving at Mars will have weak muscles because he or she would not have used them as they normally would on Earth. More importantly, when the astronaut lands on Mars, he or she will experience gravity as much more of a force to reckon with than they had ever noticed since departing Earth.

An additional consequence of leaving gravity is that the astronauts no longer require the full strength of the skeletal and muscular systems for support of their "upright" posture. This is because the astronauts do not stand up in space. Since

their muscles and bones are not used, they depreciate or "decondition" somewhat [5]. As a consequence, their bones lose calcium and become weaker and, to a degree, waste away. Bone mineral loss in astronauts has been documented in most early human space flights. Changes in calcium balance, decreased bone density, and inhibition of bone formation have also been reported. Data from Soviet/Russian flights suggests that diaphyseal bone formation may stop during weightlessness; the rate of elongation of long bones in the body is not affected by weightlessness, but the rate of circumferential growth diameter is decreased [6]. In addition to the physical changes in bone growth, increased urinary calcium excretion has been observed in astronauts in Skylab and on other flights [3]. When bones develop and grow on Earth in the presence of gravity, they typically increase simultaneously in length, diameter, and mass; these three growth characteristics contribute to the strength of the bone. During space flight, in the absence of gravity, studies have shown that certain bones appear to grow in length at about the same rate as on Earth, but that the diameter of the bone is, to some extent, smaller. Moreover, the low level of light in space means that little vitamin D will be formed, which will also impair the absorption of calcium, resulting in even more bone loss [6].



Figure 2: An astronaut on the ISS conducts daily exercise (Photo from NASA).

For a trip to Mars, therefore, there are potential causes for concern. The loss of muscle and bone will have a dramatic impact in the crew's level of fitness. There

are, however, several recommended measures that can be taken to minimize muscle and bone loss. First, working in weightlessness does not require a lot of muscle strength, so in an effort to minimize too much muscle loss, exercise can be done onboard the spacecraft. Daily exercises include passive stretching, isometric stretching, multiple small bouts, strength training, and aerobics (Figure 2). Periodic anthropometric measurements can be taken, and weight can also be monitored, in order to increase calorie intake in the event of too much weight loss. Lastly, nutritional supplements such as amino acids and antioxidants, can be used as countermeasures. Similarly, screening countermeasures could be put into practice to help prevent too much bone loss; every effort must be made to select astronauts who have no hereditary hypercalciuria. Astronauts who have idiopathic osteoporosis or a high risk of susceptibility to kidney stones should not be selected [9]. For those who are selected, careful monitoring of bone loss is the best prevention strategy. A diet of low sodium, high calcium and vitamin D must be strictly enforced, and high impact loading exercise of the lower extremities must be done periodically. These exercises, which include squats, leg abductions/adductions, optimal treadmill sessions, and intense resistant band training, will help in maintaining bone mass. Lastly, the use of drugs such as potassium citrate can be employed to reduce the chance of kidney stones [5].

1.5 Potential Risk of Permanent Damage to Vision

The space science medical community has recently realized that long-term spaceflight can cause severe and possibly permanent vision problems in astronauts [8]. NASA researchers are conducting experiments in an effort to comprehend the issue, which, in the case of travelling to Mars, could present a significant hurdle. In the post-flight examination of 300 US astronauts since 1989, studies have demonstrated that 29% of space shuttle astronauts and 60% of International Space Station astronauts experienced significant degradation of visual acuity [8]. The space science community does not know the exact cause for the degradation; scientists believe the eye problems stem largely from an increase in pressure inside the skull, specifically, from increased pressure from cerebrospinal fluid which surrounds the brain, which works its way to the optic nerve and pushes on the back of the eyeball [8]. A spacecraft equipped with artificial gravity, which would prevent an increase in pressure in the skull, would be the recommended primary countermeasure to mitigate potential permanent vision problems.

2. Psychological Aspects of Space Travel:

Of all problems that can be encountered enroute to Mars and back, effects on the astronaut's mind may be the biggest risk factor of them all [17]. As mentioned, a round trip to Mars would take 2-3 years. Anxiety, depression, and loneliness, along with the stress of routine tasks, tensions within the crew, and a daily battle to maintain fitness and avoiding accidents, is the ideal recipe for disturbed behavior in space. Although the psychological effects of living in space for long durations have not been clearly analyzed, similar studies on Earth do exist, such as those derived

from Arctic research stations and submarines [5] [15]. Many of these studies confirm psychological stress could be the biggest problem for the crew. For example, unlike crews on the International Space Station, the crew enroute to Mars cannot remain in direct contact with their loved ones and are not steadily supplied with replacement crews, food, or even gifts. Isolation and confinement pose the greatest challenge for the crew - as they approach the Red Planet, communications between the spacecraft and Earth become sparser. For example, they would have to wait up to 21 minutes for a message to reach family members and another 21 minutes to receive a reply [10]. A variety of other psychological and physical effects have also been observed from both operational and simulated isolated and confined environments. These factors include motivational decline, fatigue, insomnia, headaches, digestive problems, and social tensions. Strained crew relations, heightened friction, and social conflict are also expected from isolation and confinement.

The experience of Russian and US long duration spaceflight has revealed the need for psychological countermeasures to support human crews in space and aid their resistance to the stressors of spaceflight. As a result, countermeasures are being developed, validated, and implemented, which seek to lessen the impact of these stressors on crews, and subsequently improve mission safety and success while lowering risk. Psychological countermeasures involve astronaut selection, training, and in-flight support. One method in development is an attempt to select-in psychologically fit crewmembers, as opposed to merely selecting-out psychiatrically ill applicants. The Behavior and Performance group at NASA is currently validating a psychological select-in astronaut selection methodology [3]. These validation studies have now discovered that several personality variables such as agreeableness, conscientiousness, empathy, sociability, and flexibility, among others, are positively correlated with astronaut performance under stressful conditions, teamwork, group living, motivation, and decision-making [3]. Psychological training focuses on developing skills for coping with the stressors of the spaceflight environment and for interacting with fellow crewmembers as well as with ground control personnel. The training also deals with leadership styles, multicultural issues, working in an isolated and confined environment, and communicating with team members. In-flight psychological support involves ground-based monitoring by flight psychologists and psychiatrists, in-flight entertainment (such as videos, books, games, and special items), leisure activities, and opportunities to communicate with the ground (i.e. with family and loved ones); it also extends to care of the families of astronauts on the ground.

The US space program is now acknowledging that psychological factors are crucial for supporting the health, well-being, and performance of astronauts and increasing mission safety and success. Accordingly, new areas of specialty within the behavioral sciences are emerging, which focus on space psychology, human factors, habitability, performance, and space sociology. Health and medical professionals supporting human spaceflight operations will benefit from data in these areas as well.

Recent studies conducted by NASA, specifically on the International Space Station, have shown that a variety of common sense countermeasures have been successful in keeping astronauts psychologically fit [11]. Some of these countermeasures, which would be adopted by astronauts enroute to Mars, include keeping busy with daily tasks, conducting physical workouts, productive use of free time, and attaining goals that contribute to mental and emotional well-being [12]. Additionally, maintaining a confidential journal allows the astronauts to vent and reflect [12].

NASA, moreover, offers psychological support to all astronauts before, during, and after missions [13]. This support includes:

- Preflight preparation training and briefings in a variety of areas;
- Family teleconferences, and;
- Preparation for the psychological hardships of long distance separation from family and issues likely to arise following the astronauts' return.

3. Long-term Food and Nutritional Concerns

Unlike short duration space missions or the International Space Station, which gets resupplied periodically, food supply becomes a critical issue for a manned mission to Mars. While the US military and FEMA currently produce food with a long shelf life, astronauts on a mission to Mars will have different nutritional needs. The food that an astronaut must consume must be of the highest quality to combat the effects of long-term exposure to weightlessness, primarily in order to maintain body mass and prevent disease [6]. Once the crew leaves Earth for Mars, no other options are accessible and any further supply of additional food must be sent months or years in advance. The cost of added weight on the spacecraft is also important and another of the problems that must be overcome prior to leaving for Mars. Furthermore, unlike most food with a long shelf life, the nutritional requirements for a mission to Mars must be designed so the crew can look forward to an interesting and varied cuisine while they are away from home. On the International Space Station and Space Shuttle (recently retired), food is prepared on Earth and requires only minimal additional preparation [14]. A mission to Mars, therefore, will require a shift to a system of production, processing, preparation and recycling of nutrients in a closed loop environment. This process is currently designated as Advanced Life Support and it involves not just the production of food materials but also regeneration of oxygen and potable water [10].

From a physiological perspective there are number of body changes that have a role in modifying food intake. For example, early-induced fluid shifts and changes in blood and total body water volume are well documented. Gastrointestinal function, moreover, may be altered due to changes in micro flora and lack of gas separation in the stomach and intestine [5].

A manned spacecraft built for Mars must have a galley, eating area, and an exercise station. Furthermore, the crew must have access to refrigerators, freezers, a microwave, an oven, and ambient temperature storage for foods. Frozen items should include entrees, vegetables, baked goods and desserts. The refrigerator, moreover, must be capable of keeping fresh fruits and vegetables. Some dairy products should be available, as well as extended shelf life produce. And, at a minimum, a 30-day [10] repeating menu with individual choice of menu within the constraints of nutritional adequacy should be provided. Other considerations factored into the menu must be a diet high in calcium and vitamin D to maintain bone mass, as well as food low in saturated fats to prevent cardiovascular disease.

4. Operational Medicine and Health Care Delivery

On a mission to Mars, the crew would not have access to an emergency room. Moreover, there will not be much room for a full sick bay, and ambulatory medical care will be out of the question. More importantly, during the astronaut selection process it is unlikely that one would know if a crewmember is in the early stages of a deadly or incapacitating disease that would develop during the journey. Although the probability is low, there are several possible situations where medical or surgical care could be required during a mission to Mars. Medical situations, which have emerged during analogous situations (for example, crews in Antarctica or on submarines) [5], include strokes, appendicitis, bone fractures, cancer, intracerebral hemorrhage, psychiatric illness, and kidney stones. Decompression sickness, moreover, is another potential problem the crew could encounter, particularly during an extravehicular activity, or when moving between two different pressure environments within the spacecraft.

The first step in mitigating any potential medical problem is to thoroughly screen crew, and implement prevention and countermeasure strategies to avoid most medical emergencies during the flight. A detailed knowledge of the crewmember and his or her genetic makeup, to account for heredity conditions, will be necessary. Screenings for potential risk for cancer, risk for cardiovascular disease, and development of kidney stones must be part of the assessment process to ensure the crew is at optimal health. Prior to, and during the flight, the crew must also follow an aggressive cardiovascular and cancer prevention program (and diet) to minimize the risk of disease [7]. The crew must have access to advanced medical kits which provide a wide range of first aid and surgical instruments. These kits must include antibiotics, allergy treatments, analgesics, stimulants, cardiovascular drugs, and other drugs for motion sickness, anxiety, depression, bone loss, and radiation protection. The crew, moreover, must be trained to conduct minimally invasive surgery, and, if needed, use advanced robotic life support such as Robonaut for trauma (Figure 3). During the flight to Mars, the crew must conduct medical refresher training and have contact with medical personnel at ground control. More importantly, it is highly recommended that at least one member of the crew is a fully

trained medical doctor or physician with extensive training in space medicine to monitor the crew while on the mission.



Figure 3: NASA is currently studying the use of robots, such as Robonaut, to provide medical care

(Photo from NASA)

Additionally, astronauts who fly together in space are typically chosen from a select group of individuals. These astronauts are handpicked based on the application of evidence-based medical evaluations and the unique combination of technical and behavioral competencies critical to success in long-term spaceflight [15]. The astronaut crew enroute to Mars will be isolated during the entire trip and thus must heavily rely on the spacecraft's onboard systems for health and safety. In addition, as the spacecraft moves further away from Earth, communications with Mission Managers could be delayed up to 40 minutes due to the large distance that radio communications must travel. Therefore, the Mars astronaut selection criteria must include a consideration of psychological and behavioral health issues related to crew performance during the prolonged lack of communication with Mission Managers back on Earth [16]. Nevertheless, the medical system developed and integrated for any mission to Mars will be more robust and intelligent than any medical care system used on the Space Shuttle or International Space Station. For example, the spacecraft would be integrated with medical systems that will function

autonomously with little or no interaction from Mission Managers back on Earth [16].

5. Exploiting the International Space Station

From 2007 to 2010, the European Space Agency (ESA), Russia, and China selected volunteers to take part in a 520-day simulated round-trip mission to Mars. Known as the Mars500 program, the volunteers were sealed in a mocked spacecraft in Moscow, Russia and took part in a study to investigate the psychological and medical aspects of a long-duration space mission. Although the Mars500 project provided valuable information as predicted, a manned mission to Mars will require long-term medical research under conditions of weightlessness, such as on the International Space Station (ISS). With the recent retirement of the US Space Shuttle fleet, the only viable option would be to use the (ISS) to simulate a mission to Mars.

The ISS is the most complex and largest international engineering and scientific project in history. It is over four times larger than Russia's Mir space station and longer than a football field [14]. The station's primary goals are to enable long-term exploration of space, and provide benefits to all people on Earth. In addition to scientific research on space, additional projects that are not related to space exploration, but have expanded our understanding of the Earth's environment, have been conducted. These experiments have included learning more about the long-term effects of radiation on crews, nutritional requirements levied upon astronauts during long-term missions in space, and developing newer technology that can withstand the harsh environment of space. Other experiments conducted over several expeditions on the ISS include:

- *Clinical Nutrition Assessments of Astronauts*
- *Subregional Assessment of Bone Loss in the Axial Skeleton in Long-term Space Flight*
- *Crewmember and Crew-Ground Interaction During International Space Station Missions*
- *Effects of Altered Gravity on Spinal Cord Excitability*
- *Effect of Microgravity on the Peripheral Subcutaneous Veno-Arteriolar Reflex in Humans*
- *Renal Stone Risk During Spaceflight: Assessment and Countermeasure*
- *Validation Effect of Prolonged Space Flight on Human Skeletal Muscle*
- *Bodies In the Space Environment: Relative Contributions of Internal and External Cues to Self*
- *Orientation During and After Zero Gravity Exposure [14].*

Conclusion

Over the past few decades, a variety of proposals have depicted spacecraft that are capable of completing a round-trip mission to Mars. Many, if not all, of these technical proposals can be used to build a spacecraft using today's technology. More importantly, any spacecraft built for such a mission would be an international effort of epic proportions. The spacecraft itself, however, is only a part of the solution for developing a successful mission. As mentioned in this paper, there are still many physiological and psychological challenges the crew destined for Mars must overcome. Although dozens of astronauts have been used as test subjects for physiological and psychological experiments, and preventive strategies and countermeasures have been implemented, we still do not have a lot of knowledge concerning long-term exposure to spaceflight. We can learn more about long-term exposure to a weightless environment, and how it will affect a manned mission to Mars, by simulating such a mission on the International Space Station. At a minimum, a crew can spend two years on the station to simulate the amount of time it would take to travel to Mars and back (not counting the amount of time spent on Mars waiting for point of departure). We can use the time spent on the station to continue with additional scientific and medical experiments to determine the effects of long-term exposure and, more importantly, develop additional (or better) countermeasures to ensure a successful mission to the Red Planet. Ultimately, going to Mars makes sense, as it is the next step in space exploration. Unsurprisingly, there are many unanswered questions about long-term exposure in space and how it can affect the crew physiologically and psychologically. Nonetheless, we have the right technology, personnel, and pioneering spirit to address these challenges, move forward, and conquer this bold goal.

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Biography

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