Risk Management Plan Technical Report

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Abstract

Going to Mars presents several problems that engineers, scientists, and the astronauts must overcome, namely breathable air, nutrition, and crew selection. NASA must ensure that the astronauts have enough oxygen to survive the entire three-year journey. The most advanced oxygen recycling system to date is the Advanced Closed Loop System (ACLS). It will likely accompany the astronauts on their journey to Mars. Research done at the U.S. Army Natick Soldier Research, Development and Engineering Center in Massachusetts helped provide valuable insight as to what vitamins are necessary to make sure the astronauts are healthy and how to produce foods containing them that can fit on the spacecraft and last for the entire journey. They found success with a high-fat granola bar coated in a preservative saturated with the vitamins. Crew selection is the toughest obstacle to overcome as it is not quantifiable. The mental strain on the astronauts is unlike anything anyone has ever experienced and the mission hinges on them maintaining their sanity and being mentally and physically healthy enough to carry out the mission.

Keywords: Mars, breathable air, nutrition, crew selection , NASA, Advanced Closed Loop System, U.S. Army Natick Soldier Research, Development and Engineering Center, vitamins, granola bar, mental strain.

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There are a multitude of factors that go into designing a mission to Mars. There are many potential hazards to the astronauts and mission integrity. Millions of dollars and countless hours go into trying to overcome these problems so that NASA can put the first human on Mars. Each astronaut that will travel to Mars has to undergo a strenuous training program to ensure that they are prepared for every foreseeable problem that could occur during the nine-month travel period between Earth and the Red Planet. Meanwhile, hundreds of NASA employees will spend every day and night making sure the astronauts have the best possible chance for survival. There will always be risks associated with space travel; it’s just a matter of identifying and mitigating them.

# Breathable Air

One of the most fundamental elements necessary for life is oxygen. Here on Earth, there is a plentiful supply of it thanks to the various cycles, like photosynthesis, but, in space, oxygen is a rare commodity. Earth is the only planet with an oxygen-rich atmosphere, so it needs to be transported and recycled by the astronauts for the entire mission. Unfortunately, to transport three years’ worth of oxygen for several crew members is unthinkable. It would take up far too much room, so NASA had to develop a system to create oxygen seemingly out of thin air. Thankfully, the smart people at NASA figured out how to change the carbon dioxide that we produce back into oxygen. During the early Gemini and Apollo missions, it was a rudimentary process, but, today, the machinery used on the International Space Station is recycling 50% of the CO2 produced back into oxygen (Pultarova, 2018). The Advanced Closed Loop System (ACLS) was developed by the European Space Agency in 2018 and sent to the ISS for installation later that same year (Pultarova, 2018). As the latest development in oxygen recycling technology, it will likely be the module in the spacecraft bound for Mars or the blueprint that NASA will use to design its own tailored system for the Mars mission. The astronauts will all be trained to maintain the ACLS as it is one of the most crucial elements of the mission. If the ACLS fails, the astronauts die.

Such an event almost occurred during the Apollo 13 mission when the oxygen tank exploded and forced the crew to seek refuge in the lunar lander. The engineers never thought about this situation and the lithium hydroxide canisters that removed CO2 from the air from the command module were not compatible with the lander’s openings for replacement canisters. After some brilliant MacGyver-ing by the engineers on Earth, the astronauts were able to fix the problem with a combination of plastic bags, cardboard, and duct tape. After this, the canister openings were made a universal size and shape on all spacecraft. This goes to show how important the oxygen recycler is on any spacecraft, especially on a mission to Mars. The Apollo 13 crew had to survive for 4 days. The Mars mission crew will be months away from help if something goes wrong.

# Nutrition

Astronauts do not have the luxury of regular food during their three-year journey to Mars and back. Food must be compact enough to store a three year supply for several astronauts aboard the spacecraft, provide all the nutritional value the astronauts need, and be able to survive the harsh conditions aboard the spacecraft (Boyle, 2018). This problem has been the bane of food scientists since the Gemini Program 60 years ago. The astronauts will be able to grow a small crop yield of lettuce, potatoes, and other vegetables during their journey, but they will still have to rely on vitamin supplements to give them their necessary daily nutritional value (Boyle, 2018).

Studies at the U.S. Army Natick Soldier Research, Development and Engineering Center in Massachusetts by food scientist Ann Barrett – under a grant from NASA – have yielded interesting results regarding what vitamins are necessary for the astronauts, how NASA can package them to make them taste better and last for the entire duration of the mission while giving them their vital nutrients (Boyle, 2018). She conducted an experiment over the course of three years, the estimated mission duration for a mission to Mars, involving two different varieties of granola bars that were coated in a preservative full of the vitamins necessary for survival: “vitamins A, thiamine, folic acid, C, and E” (Boyle, 2018). Then, Barrett and the team of researchers assisting her made low fat and high-fat versions of the granola bars to see which would prevent the vitamins from dissolving and maintain the flavor of the bars. They then stored the bars for a year before testing them for vitamin content. They repeated the procedure over the next two years before, at the three-year mark, bringing them out and allowing people to eat and critique them (Boyle, 2018). The results showed that the low fat bar broke down, lost vitamins, and lost its taste the fastest (Boyle, 2018). The high-fat content of the other granola bar helped the bar cohere better and preserve the vitamins and taste (Boyle, 2018).

This invaluable research will help scientists produce better food that the astronauts take with them to Mars. It is crucial to their survival that they stay at the highest level of health possible so that they can complete their mission. Space and Mars are harsh, unforgiving environments and astronauts need to be physically fit to handle anything that gets thrown at them. Food also plays a large part in the spirit of the crew. If they had to eat the same tasteless food for nine months, they might be less keen to eat, and it might add to depressive qualities that might develop during the mission. NASA needs to keep a steady variation in the type of food to help keep the astronauts happy, while still giving them the nutrients they need.

# Crew Selection

While the physical health of the astronauts is very important to the integrity of the mission, the mental health of the astronauts is just as, if not more important. The mental strain that will be placed upon the brave men and women who venture out into the abyss is unfathomable. The multitude of effects that the astronauts are expected to experience will take a large toll on them and only the most mentally strong candidates must be considered. To help gain a better understanding of how the conditions will affect the astronauts, a group of researchers from the Institute of Biomedical Problems of the Russian Academy of Sciences conducted an experiment called Mars500 Project (Weir, 2018). It involved six participants, all from military or engineering backgrounds, that volunteered to live in a simulated space capsule for 520 days to simulate the conditions that astronauts would face during the journey (Weir, 2018). By leaving them in the capsule for 520 days, they face the most daunting challenge: time. The astronauts will be forced to live in a small capsule hurtling through space with several other people for nine months at a time for both the trip to Mars and back. The researchers wanted to analyze the effect of being in such proximity to the same few people for such a long duration. There is a large potential for the astronauts to become hostile towards each other as their stress reaches the tipping point, but research on such prolonged experiments is far and few in between (mostly consisting of submarine crew mental examinations), so the Mars500 Project provides important insight.

The next step to replicating daily life onboard the spacecraft was to make the test subjects perform routine maintenance and research using the instruments they have in the capsule. This will be the main objective for the astronauts during their travels. It should help keep them focused and give them something to occupy their time, as well as providing important data and experiments for NASA.

To further immerse the test subjects, their “mission control” contact, the only people allowed to talk to them, maintained a strict 20-minute delay on any messages being received or sent back to the capsule to mimic the sheer distance that messages have to travel to and from a spacecraft and mission control on Earth. The effect of having your messages slowly take longer and longer to get responses could have a profound effect on the astronauts. Messages from mission control will take too long to respond to emergencies to help the astronauts in most cases, so astronauts must learn to deal with everything on their own. Any messages they send could take an hour to get a response, so effective problem solving and decisive decision making is a major skill to look for when choosing the candidates for the training program

The last major challenge, as small as it may seem, was that there was no day-night light cycle. With no reference point, the test subjects’ circadian rhythms became confused and made their sleep patterns irregular. They reported insomnia and physical exhaustion due to the lack of deep, replenishing sleep (Weir, 2018). Their bodies began to enter a hibernation-like state to minimize energy loss and they became much lazier and tended to lay around when they were not engaged. This problem can be fixed by lighting systems that slowly dim and brighten to stimulate the astronauts’ circadian rhythms, although it may not be enough to maintain a stable sleep pattern.

By the end of the experiment several problems had arisen; the test subjects showed signs of mild depression, insomnia, anxiety, and stress (Weir, 2018). The two test subjects with the highest levels of stress and exhaustion alone caused 85% of the conflicts between the test subjects and with mission control (Weir, 2018). This goes to show that just one astronaut could compromise the mission and puts increased pressure on NASA to choose the very best candidates to give the mission the best chance of completion.

To help cope with these effects, astronauts will have to undergo strenuous training. This could involve isolation chambers and prolonged confinement to help them develop coping techniques for being stuck in such a small space with others. Their psychoanalysis will be studied thoroughly by psychologists to help develop personal training programs to better fit each astronaut’s personality. It will not be fun work, but it will be paramount to the success of the mission. Research on submarine crews will be prevalent in their training and should be referenced for potential coping mechanisms, side effects, and additional features that might be implemented on the spacecraft to help them, like different color palettes and lighting. While NASA can do a lot to help the astronauts, it will come down to their mental fortitude upon entering the program that will determine their ability to withstand the pressure and anxiety associated with the journey.

# Conclusion

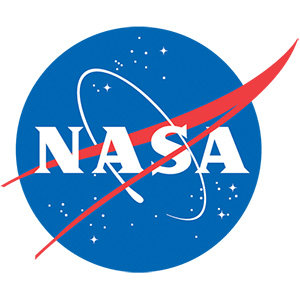
The journey to Mars will be one of, if not the, most difficult undertakings in the history of humanity. There are a million things that could go wrong in a million different ways. Luckily, the brightest engineers and scientists are working day and night to make sure that, soon enough, humans will step on the surface of the Red Planet. By and far the most difficult challenge that NASA will face is the crew selection and psychological effects of long-term space travel. NASA can calculate how much oxygen or food the astronauts will need, but they cannot quantify the mental strain on the astronauts. Nobody has experienced what those astronauts will go through, so NASA does not know exactly what will happen until it’s too late to come home and try again. They can help the astronauts cope with the experience, but they cannot control their reaction. The astronauts could train for two years and still manage to compromise the mission because their stress levels go over the brink and they cause a problem. It is by no means impossible, but it will be a great risk.

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Going to Mars is no cakewalk, even for NASA. There are dozens of problems that NASA engineers and scientists must solve before we send the first men and women to the Red Planet. One of the most fundamental is the need for food. Astronauts need several key vitamins to stay healthy, but NASA also must fit three years’ worth of food in the tiny spacecraft. This means that the food must be compact, yet nutritious and be able to last for all three years. Food Scientists at the U.S. Army Natick Soldier Research, Development and Engineering Center in Massachusetts have been developing various ways to keep the food interesting, yet nutritious for the astronauts, like granola bars. Astronauts can count on a large variety of foods to eat on their long journey to Mars.

The next problem is the need to breath. The oxygen in the spacecraft will only last for a few days at best, so NASA must be able to produce oxygen on the fly. To accomplish this, NASA invented a compact machine that turns the CO2 the astronauts exhale into oxygen and methane. They can then vent the oxygen back into the cabin and keep the astronauts alive. This technology has existed for some time, but the latest and greatest version is the Advanced Closed Loop System (ACLS). The ACLS was invented by the European Space Agency. It is currently deployed on the International Space Station to make sure the astronauts can breathe easy knowing that they’ll always have a source of fresh oxygen.

The biggest hurtle for NASA is the psychological effect on the astronauts. They have to make sure that the candidates selected are strong enough mentally to handle the gravity of the situation. Not everyone can be in a small space with five other astronauts for nine months at a time while trying to carry out the biggest endeavor since the moon shot in 1969. The astronauts will be trained for two years to help cope with the stress. NASA is confident that they have the best astronauts on the planet and that they are more than capable of being the first humans on Mars.