Risk Assessment and Management Plan

Technical Report

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Abstract

The risks of space travel are of utmost importance to consider; three large factors will be reviewed within the body of this report. Radiation, reduced gravity, and waste mitigation will be focused on and these three factors will be framed in the context of traveling to Mars and Mars’s surface. A general discussion will also be partially outlined on these factors. Ultimately, multiple actions will be discussed to independently address each of these issues in an attempt to reduce their influence on most interspace travel missions, especially those to Mars. One of the risks will also be viewed as especially dangerous and taken with the most precautions. This paper will also attempt to demonstrate that despite these risks, space travel produces a net positive for humanity, and a message to the public will be provided at the end to create better public sentiment and support for interspace travel missions.

*Keywords*: risks, radiation, reduced gravity, waste mitigation, interspace travel

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Interspace and interplanetary travel have long been a part of humanity’s dreams and are increasingly becoming more and more plausible. Earth’s moon has already been conquered so humanity looks to Mars as the next target for landing. Although interspace travel is a goal many try to achieve, it will always come with its fair share of risks. While there are many risks, three stand out as being crucially important to address and difficult to do so: radiation, reduced gravity, and waste mitigation. These three risk factors are large obstacles against interspace travel and create a necessity for plans to deal with each of them. Safety is and has always been the number one priority of NASA and other space-traversing organizations. Despite these obstacles to safety, interspace travel must be conducted and these obstacles must be overcome.

**Radiation**

Radiation is extremely dangerous to astronauts and biological life in general. In short, radiation -- for this discussion -- comes in the form of subatomic particles or waves from the sun and outside the galaxy that travel at near light speed (Tate, 2013). Radiation transmits energy through empty space and releases that energy when it comes into contact with some other entity, such as the genes of an astronaut (Tran, 2019). Deoxyribonucleic acid (DNA) is the macromolecule of genes and programs a cell’s life through proteins or the lack thereof. Some radiation particles and waves are easily able to penetrate most materials by circumventing them or simply going through microscopic holes. When radiation comes into contact with DNA, it damages it by destroying bonds and essentially knocking out nitrogenous bases -- building blocks of DNA that determine what protein will be created -- into other parts of the DNA chain, possibly creating a denatured (misshapen) protein (Garner, 2015). On a macroscale, this can cause a wide spectrum of issues for any biological tissue, making radiation extremely dangerous. On Earth, the presence of a strong and functional magnetosphere and atmosphere protects life from most radiation, with the exception of some that manages to penetrate them both (Williams, Nov. 2016). Mars does not have any magnetosphere and a very thin atmosphere, making it a hot zone for a constant bombardment of radiation (Williams, Nov. 2016). Mars has a high radiation count of up to 20 rem/year and as low as 10 rem/year (Williams, Nov. 2016). Space itself is similar, where the only natural protection from radiation would be in Low Earth Orbit (LEO); the International Space Station (ISS) presides in here (Tran, 2019). Radiation poses a direct threat both in interspace travel and on Mars itself. There are some methods that have been used and are in development that can potentially minimize the risk posed by radiation. For interspace travel, NASA could create spacecraft with more mass and material that would absorb or reflect the radiation (Garner, 2015). Naturally, this comes with higher costs of fuel and material (Tran, 2019). Another is to synthesize some material that can efficiently absorb or reflect radiation. Hydrogenated boron nitride nanotubes (known as BNNTs) seem to be a promising material for this job and may be used to be woven into spacesuits for both interspace travel and planet exploration (Garner, 2015). A magnetic force field could be used to reflect radiation, similar in concept to Earth’s magnetic field (Garner, 2015). However, this may be too costly due to energy expenses. Relocating a Mars base to a lower altitude area, such as the Hellas Planitia region, would minimize radiation as well (Garner, 2015). Lastly, the base could be underground or incorporate a large mass of planetary material covering it, but this may not offer full protection (Tran, 2019). There is still a large amount of research that must be done in order to maximize efficiency of current methods.

**Reduced Gravity**

Microgravity/reduced gravity also serves as a serious risk for interspace travel. The term “reduced gravity” simply refers to the lessened gravitational force enacted upon the astronauts, the spacecraft, and equipment. Zero gravity (or zero Gs) is usually not perfectly attained since gravitational fields extend infinitely, although losing strength the farther an object is away from the object producing the gravitational field (refer to vector force fields for further study). Earth’s gravity is the standard 1 G unit (9.80 m/s2 approximately) and is used as a comparison to other gravitational fields. When a human is subject to gravity under that of normal Earth conditions, many health risks can be present. Two common effects are muscular and skeletal atrophy. Due to a lack of necessity for more muscles and bone density because there is less force against the body, bones and muscles deteriorate (Howell, 2017). Astronauts also suffer a redistribution of body fluids, most notably with blood, causing more blood to accumulate in the head as opposed to more blood accumulating in the feet and legs in 1 G (Demontis et al., 2017). This causes space motion sickness but is usually gone within 2-3 days. This fluid redistribution also affects the eyes, possibly causing ocular damage and reducing near-sight vision (Demontis et al., 2017). These problems would both be present on Mars and interspace travel; however, they would be significantly exacerbated in space as opposed to being on Mars. Mars exploration would exhibit less of an issue with reduced gravity because Mars has 0.376 Gs, with a gravitational acceleration of about 3.71 m/s2 (Williams, Dec. 2016). In open space, astronauts would face virtually 0 Gs. There are already countermeasures for these issues but have room for improvement. Physical exercise is an excellent way to counter some muscular deterioration but is not enough for some muscles like the calves (Demontis et al., 2017). One crew aboard the ISS used a “bicycle ergometer, a treadmill, bungee cords, and an elastomer providing a resistance exercise, the Interim Resistive Exercise Device” (Demontis et al., 2017). Calf deterioration is almost inevitable and some rehabilitation efforts would be needed when the astronauts would return to Earth. An exercise machine has to be formulated in the near future in order to counteract deterioration. For fluid redistribution issues, a mechanical counter-pressure suit may help with maintaining balanced blood pressure values inside the human body (Demontis et al., 2017). It would “apply a steady pressure against the skin by means of skintight elastic garments” (Demontis et al., 2017). The SkinSuit, one developed in 2015, showed potential by also counteracting the stretching of the spine in space, which accounted for back pain experienced by some astronauts (Demontis et al., 2017). The fluid redistribution should aid ocular fluid pressure as well, theoretically. A one-size-fits-all solution could be to simulate 1 G of gravity in space or on Mars. By using a centrifuge-like chamber, gravity could be simulated through the centripetal force of the chamber. As outlined in the study, “an optimal solution could be represented by a combination of centrifugation with (i) intensive aerobic exercise for cardiovascular system protection and (ii) moderate exercise to prevent musculoskeletal system deterioration” (Demontis et al., 2017). There are still issues to this solution as it is not viable to astronauts due to the Coriolis effect and centrifugal force both contributing to motion sickness. It may also be difficult to implement because of energy costs and engineering requirements, but it provides the best theoretical chance.

**Waste Mitigation**

There are many forms of waste that can be generated on long-duration interspace travel, whether it be a chemical byproduct of an experiment or human waste. The primary risks of waste build-up are that it can harm astronauts and simply keeps unnecessary mass on the spacecraft (Mahoney, 2013). Waste will especially pose a problem in long-duration interspace travel. This is because typical waste management is composed of simply putting waste into pods that are sent back to Earth to either burn up in the atmosphere or land back on Earth; however, this method only works for missions in LEO (Linne et al., 2014). During the actual flight, there are many methods to deal with this. One is to utilize the waste by converting some, if not all, of it into useful gases (Herridge, 2018). Technologies by NASA currently exist to complete this task. Waste on Mars could potentially be treated the same way, or used to create fertilizer if endeavors to pursue agriculture are taken (Linne et al., 2014). The crew would need to be trained on the exact processes of waste conversion and in utilizing the machines given to do such a task. Waste mitigation will most likely not prove much of a risk as there are already numerous effective methods, although there is space for improvement, to deal with waste.

**Conclusion and Danger Analysis**

The larger the goal, the more risks it comes with, but overcoming those risks ultimately makes achieving the goal substantially more satisfying. Examining the sources, radiation proved to be the most dangerous of the three risks present with reduced gravity coming in at a close second. Radiation is the most dangerous due to the fact that it is very difficult to stop (takes the most resources) and can cause a variety of life-threatening effects. It is true that reduced gravity may also cause irreversible effects but those are generally more rare and could be mitigated somewhat. Radiation, on the other hand, poses a very general threat to safety. There is still a need for further research on these three risks, as well as the other risks involved. Although current ideas may be suitable for some tasks, there are ultimately many more efficient methods that are potentially available given further research and testing. Without consideration of these risk factors, a successful Mars mission is not possible, and therefore, the utmost care must be given to them, especially to radiation.

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**The Cost and Benefits of Space Travel**

Almost every child has dreamed of soaring through space as an astronaut -- it is a really cool job after all. But like all great adventures, there are always some risks involved. Some big risks include radiation, reduced gravity, and waste management. Of course, there are others too, but those three are pretty big in the world of astronauts. Before any astronaut is ready to travel, there are members of the team that have to think about how to deal with risks.

Radiation may sound familiar. Simply put, radiation is usually small particles or waves that can carry and exchange energy to something else, like an astronaut. When radioactive particles or waves interact with an astronaut, they go through the skin, muscles, and bones and into the cellular level, messing up the DNA (the large molecular chain that codes for what a cell does) and causing all sorts of mayhem to a person. Radiation can be serious in large doses. On Earth, radiation is not really a problem because of the magnetic field, but in space, it is as if a person is getting multiple X-Rays in a week.

Gravity is what holds down objects to the Earth, and anything else with mass. In space and even other planets, gravity can differ dramatically. In space travel movies like *Interstellar*, it looks like the actors may be floating at times. They would be experiencing zero gravity -- nothing is holding them down. This may seem like fun but it can have some bad impacts, like deteriorating muscles and a decrease in bone mass and density.

Just like on Earth, astronauts have trash to get rid of. Waste can take up space and even cause harm to the astronauts. Astronauts also have to go to the bathroom too, but they do not have a plumbing system and toilet like they might on Earth. Waste can be a tricky problem and always has to be dealt with.

Even though space travel can be scary, there are many methods to try and reduce all of these potential risks. For radiation, materials are currently being developed to block dangerous particles and waves. Exercise has long been used to stop muscle and bone deterioration and new exercises are being created to further combat this issue. Even with waste, astronauts can convert waste to useful materials to help them with their mission. These risks can always be prevented and like anything worth it, there is always a lot of preparation involved. The vast amount of knowledge we could learn would benefit humanity in so many ways. But it all starts with patience and considering the risks so the astronauts can be safe and ultimately help out humanity.