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Humanity and Space

Radiation protection methods for future space colonization efforts

An Interactive Qualifying Project Report
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by

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Abstract

One of the largest obstacles preventing humanity from entering the new era of celestial colonization is space radiation. We have researched and theorized potential solutions to overcome this astronomical obstacle. The use of Near Earth Objects, radiation-resistant materials, and human bioengineering methods are critical measures that must be utilized to safeguard those undertaking the journey through space. The ideas outlined in our paper will allow the development and implementation of protective measures against radiation in future space-related endeavors.

Executive Summary

As it stands, space radiation is a major hurdle that prevents humanity from exploring and colonizing space. However, we have determined that this problem is surmountable within the century using clever ideas and space-related scientific advancements.

Our team has researched, developed, and proposed solutions that allow astronauts to travel through space without harm from space radiation. We have accomplished this through the perusal of cutting edge news articles, the extensive review of scientific papers, interviewing WPI professors, and the investigation of advice from our advisor. We have also extensively collaborated with another project group in the pursuit of finding more information on the aeronautical physics behind Near Earth Objects (NEOs). Through our combined efforts, we have gained a deeper understanding on the use and the implications of NEOs.

We have based the focus of our research on a series of fundamental questions that needed to be answered in order to develop a solution to the radiation threat in space travel. Foremost, “what is radiation and why is it harmful?” Our group has answered this question through the research of scientific articles and the detailed evaluation of case studies outlining the biological effects of radiation on humans. To answer “how much radiation is in space”, we found and analyzed the data accumulated by NASA and other space agencies, and researched the individual sources of radiation in space. Doing this allowed us to conclude that there is no specific amount of radiation in any particular location, but, instead, that it is constantly changing by nature. After evaluating this data, we culled cutting-edge materials that can be implemented in future studies to protect humans from radiation en route to new planets to be colonized. Ultimately, we provided a solution to the problem of how humans can be protected from radiation.

The use of NEOs as transportation throughout the solar system almost completely removes the exposure of deadly radiation to astronauts. We have hypothesized through our research that the radiation that astronauts will still be exposed to can be combated through advancements in radiation shielding and making humans more resistant to radiation.

Space colonization is essential to the survival of humanity. If we are unable to develop methods to safely expand our celestial footprint, our species will forever be at the mercy of an apathetic

universe. Through our research, we have found that through the use of NEOs and other supplemental radiation protection, astronauts will be able safely travel through space.

Chapter 1: Introduction

Motivation

Tom

My motivation for doing a project on Space exploration and humanity was that I found this topic to be of high interest to me and also, this was a topic that knew absolutely nothing about. I recognize that as the age of humanity grows older every day, our home planet Earth becomes less and less able to support the never-ending growth of humanity. This continual growth has negative effects such as the pollution of the Earth with the example of man-made products damaging the atmosphere and span as far as the problem of overpopulation. In being aware of these soon-to-be serious problems that humanity will face, I personally believe that the need for expansion and more specifically, expansion into space, is critical to the survival of the human race. I chose to work on this project as a way to introduce myself to some of the problems that lie in the way of humans being able to colonize another planet in addition to this project offering me a chance to explore a topic of high interest to me that is not in my area of study, Civil Engineering.

Justin

The topic of space colonization itself was extremely captivating for me when I heard about this particular IQP project. I have a big interest in astrophysics and astronomy as second to my major study of field. When I heard about a project that dealt with the challenging feat of human space colonization I was unable to curb my infatuating interest. This was an opportunity of a college student’s career that was not meant to be missed up on. I even compared this project to others that I was looking into for my IQP. Ultimately, this project stood out the most as I had the greatest interest in dealing with society and space.

Marc

The allure of this project stemmed from the opportunity to work on a topic that has interested me since I can remember. The concept of outer space and everything that relates to it, has always fascinated me, and is likely a topic about which many children daydream. Taking this project meant I would be able to actually contribute to the massive repository of knowledge on a topic that I have spent my entire life wondering about, which is breathtaking to say the least.

However, apart from documentaries on PBS and The Science Channel, I remained quite ignorant in the subject matter. The opportunity to immerse myself in a project initially filled with mystery and unknowns, and the promise of eventual enlightenment, was too appealing to pass up.

Relation to Course Study

Tom

Although this project does not relate to what I would like to do with the rest of my life as a Civil Engineer, it did however allow me to develop my skills in working with others toward a common goal, which for us was to analyze human radiation exposure in space and develop a method to shield against it. Furthermore, this project helped discipline me in the sense of gaining experience with working under deadlines and having to have things done on a scheduled basis.

Justin

My major in Bioinformatics and Computational Biology is very relevant to several areas of our project. I have been able to contribute a lot to the study of biological effects of radiation to humans as well as the field of bioengineering. My academic major consists of a mix of the fields of Biology, Chemistry, Computer Science and Mathematics. All these different academic areas that I have been exposed to have helped me to tackle a project with a wide variety of problems. Bioengineering is a vastly important field to the future of human society as well as future space colonization/exploration. I believe the studies that I have taken in my major prepared me well to figure out a solution to how human society will use bioengineering to protect humanity from radiation threats in space that we will have to deal with in the near future.

Marc

This project does not directly relate to my course of study at WPI. However, in the more general sense, this project has similar qualities to the classes that I often take. Most notably, this project demanded large amounts of effort and creativity and, by the end of it, has a large payoff. I was able to significantly increase the breadth of my university-level knowledge by completing this project.

Relation to and Impact on Career Goals

Tom

Some of the goals that I have set for myself, upon starting my career as a civil engineer and relating to this project, was to learn how to how to work as a team, to learn how to present my work neatly and more organized, and to develop the skills needed to be successful in a professional environment. I strongly believe that this experience has far exceeded these goals as my accomplishments for this project are certain to be helpful for me as I come closer to entering the real world. This IQP has taught me how to not only become familiar with an unknown topic but also to find new ways to contribute to it.

Justin

This project is very relevant to my career goals and passions. My academic major gives me many different options of fields to go into in the future such as working in computational astrobiology in the future or bioengineering. This project gives me a vast background of information that would prepare me for a career in those fields. Since this is a group project, I have been able to develop more skills in collaborating in a group with others working to accomplish a common goal. In the future I want to become a pioneering leader in my field who is able to work with people who have similar passions as I do. This project gives me the ability to present and display my work that stems directly from my passion to contribute to human society in the form of scientific discovery. I have been able to successfully present my findings to my professor and group members as well, which gives me public speaking practice that is vital to any future career that I will choose to pursue.

Marc

This project is ambitious. Tackling a problem that scientists have been working on since the realization of outer space is indeed intimidating. However, knowing that I will be able to add even the slightest bit of information to humanity’s knowledge of space is encouraging. This attitude is directly related to the one I carry when facing my career goals. I plan to become an entrepreneur and I hope to develop a largely successful company within the decade. I realize that this is an ambitious goal, but I know that by putting forth the required effort and never ceasing to be curious, I have a chance at completing it. This project and my career goals both require determination and aspiration, qualities that I deeply enjoy expressing. The completion of this project proves that I am capable and willing, and it gives me hope that I will be able to achieve my career goals.

Qualifications for IQP

One of the main reasons that this project qualifies as an IQP is that it has a component that focuses on the societal aspects of how space colonization will affect humanity as a whole in the next 50 years. That is the main qualification for this project's status as an IQP, because it concentrates on how human society is impacted.

One opinion on this project, as I believe fits perfectly in the category of what an IQP is supposed to be, is that it focuses around the idea of finding ways through innovations in science and technology for humanity to survive. This project allowed us to become familiar with the kinds of effects on society that the colonization of another planet would bring like, a possible result in the evolution of humans, and new changes in technology to help improve conditions already found today as well as the new ones in another world.

Project Objectives and Benefits

The overarching objective of this, and related IQPs, is to understand what technology we, as a society, need to develop in order to colonize space in the next century. Our IQP focused on the technology needed to protect astronauts from the omnipresent space radiation. The two primary goals for this project were to understand space radiation and its effects on humans, and develop visionary methods to protect against it. We feel that we have accomplished both. As individuals, we hope to have given a meaningful intellectual contribution to the field of space colonization.

Throughout this project, we have accumulated a vast store of space related knowledge and learned new skills and ways of thinking from each other as well as the professor. The most beneficial part of this project was that it challenged us to think outside of the box and learn to be more creative by trying new ideas. It was very rewarding for us because each and every day we felt that we learned something new, whether it was from doing research on a new topic, or learning how to present new ideas to the group.

Dissemination

We would like to see our group's work become published in a scientific journal. We have collaborated with another IQP group to collect and summarize our research, findings, and ideas. We believe that a publication is one of the best ways to disseminate our results because of the incredibly large audience that subscribe to and read articles in scientific journals. Because our IQP focused on a relevant problem in the scientific community, we believe that readers will be interested in what we have to say.

We plan on providing the WPI faculty who have helped us and expressed interest in our project with a copy of our paper. In addition, we will apply for the President's IQP Awards which will raise awareness and hopefully result in acknowledgement of superior work.

Chapter 2: Background Information

Physiological Effects of Low Gravity

One of the complications in space travel and colonization is the negative effect low gravity has on humans. Living on earth, humans are both consciously and subconsciously used to being under the influence of Earth's gravitational pull. As a species, we have adapted to develop under it and take advantage of it. It is unknown whether or not we will develop correctly when in an environment with a gravitational pull inconsistent with the one on Earth. However, since we have been able to experience zero gravity while in space, and experience a lowered gravity on the moon, scientists have been able to do preliminary research into the topic area.

Astronauts that have returned from moon missions have suffered the effects of the lowered gravity. Albeit comparably short-term, the data we have from their experiences can help us provide solutions. The optimal solution seems to be to simulate a higher gravity on moon colonists, but I am not sure how feasible that is. Regardless, we do have other ways to protect against the harmful effects of low gravity. These effects are described below, and possible solutions are discussed afterwards.

Muscles quickly atrophy in space because they aren't being used to resist gravity. Their mass will decrease at a rate of 5% per week if not being used. When back under "normal" gravity (i.e., gravity on Earth), muscles that have atrophied can be recouped within a month.

Bones atrophy at a slower rate than muscles, but also take much longer to recover. Bone mass is lost at a rate of 1% per month in zero gravity, with a total loss reaching 40%-60%. It can take two to three years of living in normal gravity to recover the bone mass lost on a three to six month flight. Exercise is essential to restoring both muscle and bone mass.

In low gravity, there is a diminished blood gradient throughout the body. (Expectedly, there is no blood gradient in zero gravity.) This means that there is an equal amount of blood in the top half of the body as the lower half. On Earth, gravity creates a gradient so the blood pressure in the feet is around 200 mmHg, and the blood pressure in the head is around 80 mmHg. Since the body is used to this gradient, when experiencing a diminished blood gradient (with blood pressure at a uniform 100 mmHg throughout the body in 0g), it thinks that there is too much blood in the body (since there is an unusually high amount in cranium), and thus produces less. This leads to a significant loss of blood volume, topping off at a 22% loss within three days. Luckily, this can be restored within a few days back on earth.

Due to the lowered amount of blood in the body, the heart pumps less, and can atrophy easily. Additionally, due to the increase of blood in the upper body, the pressure behind the eyeballs increase. This can lead to the optic nerve being crushed slightly, which poses a serious threat to one's vision.

There is also the concern of chronic motion sickness. In a zero gravity environment, the body does not have signals to tell it where “down” is. This results in a motion sickness similar to what we experience on earth. It is, however, more dangerous in space because vomiting could be fatal if in a space suit or near delicate equipment. Astronauts take medication to suppress the nausea.

To overcome these complications, it is necessary to maintain a high level of fitness. Doing so prevents muscle atrophy, and also helps keep the body healthy in general. Since the people on the moon will have no one to help them but themselves, it is vital that they are able to move around and exert a high level of effort when the need arises.

It is very important to take care of the body as a whole. One cannot put high loads of stress on the bone and not take care of the blood flow to that bone if you wish for the bone to recover. It is for this reason that simply exercising on the moon is not enough to keep healthy. There must be a way to stabilize the blood gradient, allow for muscles to be exercised, and allow for bone mass to increase.

There are several devices that have been developed to assist with restoring muscle and bone mass, and the body's blood gradient. Russia has experimented strapping joggers to treadmills with bungee cords. While this makeshift fix works in the short term, it does not allow astronauts to exercise to their potential. A more advanced solution is the Interim Resistive Exercise Device, iRED (see Figure 1).This device consists of canisters that provide resistances of over 300 pounds. It artificially creates the resistance needed to exercise productively. Another device invented is the Lower Body Negative Pressure (LBNP) device (see Figure 2). This chamber applies negative pressure to one's lower body. It allows its users to exercise with 100%-120% of their Earth weight, and also restores the blood pressure gradient. This is a very exciting improvement on the previous devices, as it helps to cure the three negative effects low gravity has on the body!

Fig. 1. Example usage of the iRED.

Credit: http://www.sciencedirect.com/science/article/pii/S0021929010003647

Fig. 2. Example usage of the LBNP.

Credit: http://science.nasa.gov/science-news/science-at-nasa/2001/ast02aug_1/

Further research needs to be done in order to develop an optimal solution to fight low gravity. Scientists understand the chemical signals of the brain and how they interact with each other to signal, e.g., that less blood must be produced, but we do not know how gravity is converted from a mechanical signal to a chemical one. If we could identify the mechanical signals that generate strong muscles and bones, we could make new pills and exercises to trigger those signals. Advances in research on exercise, hormone supplements, and medication can help maintain muscle and body mass.

Sunspots, Sunbursts, Coronal Mass Ejections

Sunspots are dark areas that appear on the sun when the cooler inner core is temporarily exposed. They are caused by the shifting of the corona, which is the sun's atmosphere. Intense magnetic activity occurs around the developing Sunspots, and there is a very large temperature drop in the Sunspot. This temperature shift can be observed by the black color of the Sunspot, showing that it is much colder than the rest of the Sun's surface. ž When sunspots start to spread, they can signal an increase in solar activity. As a result, Sun Bursts and Solar flares can occur and high levels of radiation and plasma emit from the Sun's surface. These emissions eventually reach the earth and spread through space. Bursts of radiation occur around sunspots in areas with high magnetic activity. This is because the high levels of magnetic activity shift the Sun's corona and creates Sunspots.

Sunbursts are immense releases of radio through gamma waves and plasma from the Sun's surface. Sun bursts that release gamma waves are the most deadly types of Sunbursts. Solar flares are less deadly compared to most Sunbursts as they release up to X-ray waves. Sunbursts interrupt satellite launches and spacecraft flights by interfering with the electromagnetic properties of the technology. ž Large releases of radiation pose threat to any living organism in space, only most powerful Sunbursts release gamma radiation which is the most dangerous. Radiation particles can strip off the electrons of an atom through Ionizing radiation, and as a result can greatly damage living organisms in space. The radiation can also cause mutations in an organism's DNA, and can cause disease. This poses a great threat to humans traveling in space.

A coronal mass ejection, or CME, is a large, violent ejection of charged particles and radiation. The types of radiation levels released from CMEs can be as deadly as gamma rays. Immense excretions of plasma also are emitted from the sun's surface. These charged particles are carried by the solar wind at speeds that can exceed 2000 km/s. As a result, it only takes a few days to reach the Earth's atmosphere. Coronal Mass Ejections (CMEs) are the most violent types of sunbursts. They can shut down entire power grids on Earth as well as leave heavy levels of gamma radiation and plasma in space. They are so powerful against electric-powered technology that in March 1989, Quebec's entire power grid was down due to a CME that hit the Earth. They pose an even greater threat to space travel. Coronal Mass Ejections are one of the main reasons for why space travel is potentially very dangerous for humans. The increase of radiation levels can pose a great harm to humans in spacecrafts. When CMEs strike the Earth, Earth's magnetosphere is disturbed with a large magnetic tail that breaks in two. A large part of the magnetic tail that splits from the magnetosphere drifts off into space. These "tails", or sheets of radiation, need to be avoided in order to maintain safe space travel for humans. Solar activity from Sun bursts occurs in cycles that peak in both frequency and magnitude. Such activity can be predicted from the Sunspot cycle. The making of the Sunspot cycle relies on Sunspot numbers, which represent the number of individual sunspots on the sun's surface and the number of groups of sunspots as well.

The Sunspot cycle can predict the occurrences of Sunspot activity, and thus Coronal Mass Ejection activity as well. This is because Coronal Mass Ejections occurrences vary with Sunspot activity. ž According to the sunspot cycle, the most violent sun bursts occur roughly every 11 years. This is based on predictions according to previous solar activity. Using the sunspot cycle, scientists can utilize the flow of sunspot activity to track the sun's cycles. This can help humanity to predict future CMEs and gather more information on how the sun works. It would make the most sense to avoid space travel during these peaks of Coronal Mass Ejection activity, as they pose great harm to humans during space travel. Avoiding these peaks of CME activity would also prevent any damages to satellites or spacecrafts that are in orbit with the plasma emitted from the CMEs.

Background on Galactic Radiation

How to Detect Cosmic rays

As Cosmic rays enter the earth's atmosphere, these rays collide with molecules that make up the atmosphere such as Oxygen, Nitrogen, and others (see Figure 13). When the rays collide with these molecules, there is a cascade of billions of smaller particles that are produced within one degree of the point of collision or the primary particle. The types of particles that will eventually result from these series of collisions are Mesons (+ & - Pions and Kaons). As these particles collide they decay or break down further into even smaller particles called Muons.

Muons are unstable Subatomic Particles that are known for having the second longest decay lifetime with 2.2 Microseconds. Muons are about 200x the size of an electron, which allows these Muon particles to ignore much of the effects of the electromagnetic fields acting on them as they travel through the atmosphere. Also due to its large decay life, these Muon particles are successfully able to travel to the earth's surface and even small depths of caves. Muons can be detected through a few different particle detectors, such as the Cloud & Bubble chambers for example.

Cloud Chambers are sealed environments that contain a supersaturated vapor (water or alcohol) that are used for detecting ionizing radiation. As these charged particles enter the chamber and interact with the mixture, the mixture becomes ionized and forms into a mist-like substance made visible by the magnetic field applied to both positive and negative particles. From this mist a curved-Shaped trail is left in opposite directions for which we can use to measure.

Fig. 3. Example of cloud chamber

Credit: http://robfatland.net/MainSequence/CosmicRays/CloudChamberConstructionDetails.html

Bubble Chambers are vessels filled with a Superheated-Transparent Liquid (Liquid Hydrogen). This liquid is used to detect movement of electrically charged particles. By filling a large cylinder with a liquid heated just below its boiling point, as particles enter the chamber, a piston suddenly decreases the pressure and the liquid forms into a superheated metastable phase. These charged particles form an ionization track which allows this liquid to begin to vaporize and turn into microscopic bubbles. During this process, the chamber is subject to a constant magnetic field (see Figure 4).

By observing high gamma ray emissions through a gamma ray telescope called the Fermi Gamma Ray Space Telescope, we can detect the cosmic ray activity on other Celestial bodies across the solar system.

Fig. 4. Example of bubble chamber

Credit: http://en.wikipedia.org/wiki/Bubble_chamber

Gamma Ray Bursts

Gamma Ray Bursts (GRB) are large flashes that originate from enormously large and energetic explosions, of which are known for being the brightest electromagnetic event to occur in the entire universe. A gamma ray burst can typically last anywhere from 10 milliseconds to a couple minutes. The explosion caused by a gamma ray burst is described as two separate explosions, an initial burst followed by an even bigger and lengthier “Afterglow”. In the initial burst, shorter wavelengths of electromagnetic radiation are emitted at almost the speed of light. Following this initial blast, the afterglow releases a larger and even longer blast made up of energy particles traveling in longer wavelengths such as x-rays, UV-rays, infrared, radio and more.

Gamma ray bursts are made up of intense radiation in a beam-like state during the collapse of a star or supernova. A supernova is a continuously rotating star with an extremely large amount of mass (see Figure 5). The cause of a GRB could result in several different cases.

A neutron star is a form of stellar remnant that is created when a massive star suffers from a gravitational collapse. (Results from a Type II, IB & IC supernova). The next result from a GBR is a Quark Star- a type of exotic star made up of quark matter (strange matter) which is extremely dense and are formed in phases of degenerate matter usually only found in large Neutron stars. The last result of a supernova is a black hole, which is known as a region of space-time where an extremely powerful gravitational force prevents anything from escaping, including light. According to the theory of general relativity, when a sufficient mass is compact enough it will deform space-time and result in a black hole and around this black hole is an area/surface called the event horizon or a point marking no chance of return.

Fig. 5. Image of supernova

Credit: http://10awesome.com/10-popular-theories-about-the-end-of-the-world/

Biological Effects of Radiation

Radiation particles contain GCRs, or Galactic Cosmic Rays, which are nuclei of atoms accelerated to high energy levels where their electrons are stripped off. Materials with the smallest mean atomic mass are usually the most efficient shields against GCRs. Gamma and X-rays pose the largest threat to humans, as they are the most deadly and raise the highest risk for causing cancer. Cancer and tumor developments as well as genetic mutations in humans are posed as grave problems dealing with radiation in space. Appropriate counter measures must be taken in order to safeguard humans against the effects of radiation in space. When energy loss occurs in radiation particles, ionization and excitation of atoms in human tissue leads to abominable results. The atoms in human tissue can be stripped of their electrons and immense damage is caused. The GCRs in radiation particles can damage humans both at the atomic level as well as the molecular level, which can have varying effects. ž At the molecular level, human DNA molecules are damaged extensively which can lead to disease. This is because mutations can occur in the genes of DNA that are affected by radiation particles, and a gene can be expressed with an abnormal function that becomes a genetic mutation. One way this can happen is that a protein with an abnormal or inactive function can produce dramatic results from the norm and can lead to severe implications. Tumors can be formed if cells lose the ability to die and other cellular pathways can lead to cancer or other diseases as well. ž

With a lack of a protective magnetic field in space like on Earth, humans are very susceptible to radiation. The SI unit for measuring equivalent radiation absorption is in Sieverts (Sv), which is defined as the equivalent absorption of one joule of energy by one kilogram of matter (in this case human tissue). Any exposure of radiation greater than 8 Sv would be fatal within days. If a human is on a spacecraft in space, the exposure from a solar flare or CME could be fatal. The radiation emitted from a CME heading towards earth could be as high as tens of Sieverts, which would be fatal. ž Any radiation exposure greater than 1 Sv can cause varying types of illnesses, such as mild to moderate levels of Leukopenia. This is a decrease in the amount of white blood cells and can lead to infections in the immune system. Due to the harsh effects of radiation, we want to look for planets to colonize that have sufficient conditions that can protect humans from harmful radiation.

One solution for this is to colonize Mars. Mars likely has less radiation than on the moon, because Mars has a thin atmospheric layer, mainly composed of carbon dioxide that absorbs radiation from space. In order to minimize the amount of radiation absorbed by humans traveling in space, it is necessary that we develop Biological countermeasures (discussed below). I think this will be very important in order for radiation damage to be minimized for astronauts in the future.

Biological countermeasures and ideas to help protect humans from radiation

Many different types of biological countermeasures can be developed in order to protect humans against radiation, as well as diagnose them for the types of diseases they can develop from radiation exposure. One of the ideas I came up with was gene therapy, which is a very prevalent and prominent type of treatment for varying diseases. Gene therapy is an interesting but promising field that could possible cure human diseases caused by radiation at the genetic level. Treatment is used to cure diseases caused by a recessive autosomal mutation, which could be caused by several environmental factors including radiation. To cure this, one can insert a dominant allele into a gene which can prevent the mutated recessive allele from being expressed. As a result the disease can be avoided. Gene therapy could be a promising field of medicine that could cure many diseases that are the results of genetic mutations. It could cure sickle cell anemia if more tests are done as well. If a disease is caused by a dominant autosomal mutation as a result of severe radiation exposure, then it can also be cured. One could simply insert a null mutation into the dominant allele, which would give the allele no functional expression. This would be used to cure many types of dominant autosomal diseases.

Another idea for biological countermeasures involves the use of biological sensors. I believe these would be useful for the diagnosis of diseases because it is a promising area of research. Biological sensors are a developing field in Biomedical Engineering that could prove to be feasible ways to diagnose and prevent certain diseases caused by radiation exposure. A sensor could be created to detect abnormal levels of a protein that is being unusually overexpressed or underexpressed. Once this activity is detected in humans traveling in space, they can be diagnosed and be given the appropriate treatment. The diseases caused by radiation in humans could also be possibly prevented. Once abnormal protein activity is detected in a human, gene therapy could be used to possibly cure the disease. Some examples of diseases with abnormal levels of protein are Marfan syndrome and Hemophilia A. Marfan syndrome is caused by abnormal protein in connective tissue. Hemophilia A is the result of low levels of protein needed for blood clotting, and can cause severe blood loss in humans. More research and funding should be put into the development of biological sensors. Another idea for curing and preventing disease caused by radiation in space is the use of tumor-suppressors. Tumor-suppressors basically prevent the development of cancer by suppressing tumor cell activity. The idea is to increase production of tumor-suppressor enzymes while humans traveling in space are being exposed to radiation. This treatment could prevent the onset of oncogenes, which are genes that cause tumors to develop. This treatment wouldn’t spread to other cells in the applied area on the human body since the surrounding cells would detect the environment and replicate to fill out the empty space. Cyclic AMP, for example, is a well-known tumor suppressor and can induce apoptosis in cells. The idea would be to inject Cyclic AMP into damaged cells that are caused by radiation damage to prevent further effects of radiation. Chemotherapy and irradiation treatments are used similarly to kill different types of tumors.

Aside from biological countermeasures, types of metallic material also can be used to deflect against radiation.

Lead is a very good shield against radiation. It has a high atomic mass and density, which is because a lead atom has small bond lengths and a small atomic radius. Because lead has such a high density and large number of electrons, it can scatter x-ray and gamma rays. This would be very effective against shielding humans against radiation if we built a spacecraft with a lead encoding. Lead is also used in x-ray machines, nuclear power plants and military devices. Aluminum is currently the primary material to build spacecrafts in NASA. However, an ideal shield would be more protective to radiation than Aluminum as well as a lighter material than Aluminum would be desired. The atomic mass of lead is 207.2 amu, whereas the atomic mass of aluminum 26.98 amu. As a result, lead is much heavier than aluminum and would not be the best material to use since it is very heavy. What humanity needs is a material that weighs less than Aluminum. Polyethylene, for example, is very useful to shield against radiation due to its high hydrogen atom concentration. Hydrogen atoms are good at shielding and dispersing radiation, and thus it would be a very effective and safe form of shielding. Polyethylene also weighs much less than aluminum and lead, which is desired. No tests have been made yet, but experiments must happen because Polyethylene could be very feasible shield material due to its physical properties.

Introduction to Near Earth Objects

NEOs, or Near Earth Objects, are comets and asteroids that have been nudged by the gravitational attraction of nearby planets into orbits that allow them to enter the Earth's neighborhood. They are classified into two groups, Near Earth Comets (NECs) and Near Earth Asteroids (NEAs).

NEAs are further classified into several groups based on their aphelion distance, perihelion distance, and semi-major axis length:

Name	*Description*

Atiras	NEAs whose orbits are contained entirely with the orbit of the Earth
Atens	Earth-crossing NEAs with semi-major axes smaller than Earth's
Apollos	Earth-crossing NEAs with semi-major axes larger than Earth's
Amors	Earth-approaching NEAs with orbits exterior to Earth's but interior to Mars'

Table 1. Classification of NEOs

We are studying NEOs for one main reason: as a method of radiation protection. That is, instead of traveling through space in a rocketship, exposed to the intergalactic and solar radiation, astronauts can land the rocketship on an NEO, bury inside, and wait out the journey. Using NEOs as a vehicle for transportation is more complicated than that, which we will be discussing later. Another reason why NEOs are beneficial is that, depending on their composition, they can provide fuel.

There are about 9000 known NEOs as of 2012.

Technical Overview of Space Colonization

Planetary Movement

If one day humans were to live and colonize other planets one should first develop and answer for how we would get there and one theory that was developed was the theory of planetary movement. One way for humans to take control of space is with Paul Birch’s theory. In an essay written by Paul Birch (published in 1993), *“How to move a Planet”,* he emphasizes that planetary movement is feasible. Birch’s theorem states that “planetary objects” can be adjusted or moved on convenient engineering timescales (~ +/- 30 years) through the use of High-Velocity Dynamic Compression Members. It is assumed that these forces are applied effectively and the moons of Saturn are interchangeably used to resist/assist these planets in motion. In order to achieve this, we will have to use a combination of angular momentum, or counterweights, and the conversion and storage of energy in dynamic compression members.

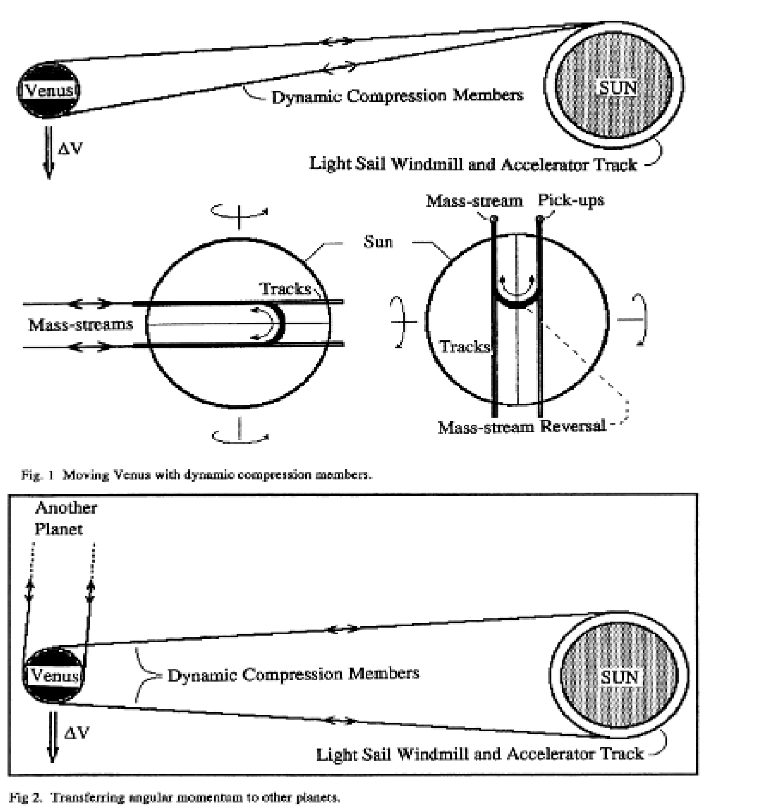

Fig. 6. Diagram for use of dynamic compression members-Birch's theory

Credit: http://www.orionsarm.com/fm_store/MoveAPlanet.pdf

The first method he suggests (similar to one of his sources) is to speed up the rotation of the target planet that will be moved, thus creating an angular momentum by slowing the rotation of the sun. This angular momentum obtained from the slowing of the sun is achieved because of the dynamic compression members being applied on the target planet(s) in motion. Next, he proposed that the kinetic energy needed to move the target planet away from the sun could be obtained through the use of a solar-orbiting light-sail windmill for which the energy created would then be transferred to a high-velocity mass stream (V > 300 kms^-1). The process for which the energy created from the light-sail windmill being sent to travel around the sun, (high velocity mass stream) is through what is called a co-circular electromagnetic traveling wave accelerator. After the high-velocity mass stream travels around the sun, it would then be sent towards the target planets limb. The counterweights would be applied in a halo orbit behind the target planet and used for supplying ~1km of water is approximately 17R (17x radius Saturn) by a moon like Tethys. Lastly, the energy stored in these Dynamic Compression Members is roughly 1.2 % of total energy needed for the High-Velocity Mass Stream to have enough Initial velocity (V >300 Kms) for the Light-Wind Sail to begin generating a continual growth in speed for affected moving object. As this generated velocity reaches its required speed, it is then shot and directed at a location near the Limb of a star or another planet.

Finally, Birch concluded that through use of High-Velocity Mass streams consisting of dynamic compression members, planets could be successfully regulated. Along the lines of mathematical data for which can be used to calculate numerically the movement of a planet, one must take into consideration that planets move in a form of elliptical motion. This form of elliptical motion is also referred to as orbital motion, which is due to the rotation of the planets about the sun at the center of our galaxy. The planets do not rotate about the sun in a circular rotation. Instead, however, their rotation about the sun is described in the shape of an ellipse. In calculating this type of motion, the results that are created are scaled from 0-1 where e initialized to zero states that the object in motion is in a circular rotation whereas an object with the numerical value of 0< e < 1 describes an object in an elliptical orbit. For objects in motion with the value of e = 1, it is a parabolic orbit for which a graph of its orbit is comparable to a continuous parabola. Lastly, values of e >1 indicates an object in a hyperbolic motion. Some of the equations used in the calculation of this e value, (e- represents the eccentricity of an orbit) is a positive number used to describe the shape of an object's motion, are shown below:

$$e = \sqrt{1 + \frac{2EL^2}{m_{\text{red}}\alpha^2}}$$

Fig. 7. Eccentricity of Kepler orbit

E- Total Orbital Energy

L- Angular Momentum

Mred - Reduced Mass

α- Coefficient of inverse-square law –Central Force such as gravity or electrostatics

Resulting from this theory of planetary movement is a new theory for energy and stellar motion. This theory includes the possibility for manipulating orbital energy and also suggests that it could also be applied to stellar motion, known as motion of stars, as we would then be able to convert to & back from orbital energy. What then would be our next step in space if we could control/move stars?

Terraforming

Terraforming another planet is the process of altering another planet's environment in order for it to sustain life. One planet for which colonization could be feasible is Venus. Terraforming Venus is the process of engineering a Global environment on Venus with goals to sustain life from Earth. The process for which the planet Venus can be terraformed (altered to sustain life) can be broken down into three closely related parts. The first issue with terraforming a planet like Venus to support life from earth would be finding a solution for Venus' deadly surface temperature (due to its Insulation Effect). The temperature on Venus is approximately 450° C which is equal to 850°F. The second and third issues are the dense and toxic CO_2 based atmosphere and that there is no breathable gases on Venus. The reasons for explaining why these issues are more important than fixing other issues found on Venus (like the problem with its extremely lengthy day/night cycle for example) is because if we found solutions to these problems, then life on Venus would be possible. Most of the other issues found on Venus mostly pertain to making life easier and turning Venus into a replica of Earth.

One solution to the problem with Venus' surface temperature would be to reduce its temperature through the use of Solar Shades. We would want to position these shades in each of the five Lagrangian points around Venus (points around Venus where the gravitational pull of Venus = Sun). A solar shade is *a* sunshield used to block or reduce a star's rays, preventing them from hitting a planet. Through the implication of solar shields being placed around Venus, this would result in a significant drop in the amount of solar energy/rays that would be hitting the surface of Venus. Therefore, this would result in a large drop in the overall surface temperature while granting a safe and comfortable environment for Earth life to exist. Also, through the use of solar shades, we would then be able to regulate and hopefully distribute solar power/light to different parts of the planet while also being able to provide shade (night) to others (solution for shortening the long day/night cycle on Venus). This proposal, although seemingly far-fetched, is a very feasible and efficient way for us to regulate the temperature of a planet like Venus at an affordable cost and in the most efficient way possible (construction of solar shades aren't overly complicated, don't require large amounts of resources to construct). I believe that the result is that a reduction in Venus' insulation problem lowers the total amount of heat stored on and under the surface resulting in a drop in overall temperature.

Moons of Saturn

Another idea for the colonization/terraformation of another planet is through some use of one or more of the 62 moons surrounding Saturn, we may be to find a way to create a planet similar to Earth (either using materials found on these moons or using the moons themselves and their physical properties). Two moons from which scientists have the most interest for are Titan and Enceladus (due to their chemical or physical composition). Titan is the only moon of Saturn that has its own clouds and an unexpectedly thick atmosphere that contains similarities to that of Earth's. Because of Titan's low temperatures (due to its distance from the sun) Scientists believe a link can be found between the earth's atmosphere during its primordial period and the deep frozen state of Saturn's atmospheric-chemical structure. These clouds primarily consist of Nitrogen but are also thought to contain even higher percentages of "Smog like Chemicals" (like Methane and Ethane) with such high densities that they precipitate as gasoline-like Liquids.

Another reason behind the importance of this moon of Saturn is because of its abundant supply of carbon compounds (basis for life on Earth) and a large variety of other important resources that would be detrimental to life on another planet. Due to the large amounts of elements found on titan, scientists will be able to perform experiments using these organic materials that have been proven to be similar to those that existed on Earth over 4 billion years ago. I believe their goal would be to study these organic chemicals and their properties. It is for these reasons why Titan is seen as the most similar celestial body to Earth.

The Second Moon of Saturn that scientists believe would be important for creating life on another planet is Enceladus. This moon is completely covered in ice & based on acquired evidence is proven to contain large bodies of liquid/ oceans underneath its icy surface. Another interesting fact about Enceladus is that its own atmosphere surrounds it. Because of this discovery, further investigation has proven that this mysterious atmosphere is actually rich in nitrogen (earth like) and could pose useful for colonizing another planet and more specifically, providing a solution to finding a source of breathable air or to rectifying the issue of creating a stable and Earth-like atmosphere.

Perhaps one of the biggest discoveries on Enceladus (besides the discovery of its atmosphere) is the ice volcanoes (also known as Cryovolcanoes) found on it. These ice volcanoes may serve as the key to the construction of a new Earth-like atmosphere because of the useful chemicals they provide (water, ammonia, Nitrogen). These ice volcanoes are located on Enceladus' southern poles and erupt with volatiles like water, methane, and ammonia. These eruptions are in forms called plumes, which are columns of fluid moving through one another. Evidence shows that these Ice volcanoes and their large emissions of gases are responsible for the creation of Saturn's E-ring.

The moons surrounding Saturn could serve as the building tools for which we can use to colonize another planet (necessary building materials & Chemical/physical composition). Although these moons contain the materials and elements necessary in constructing an Earth-like planet, the only issue really preventing this from becoming a reality is the lack of proper technology for which we can use to move these planets and or moons. We lack the technology that we could use to excavate these celestial bodies in the most efficient and cost effective way. Through further research and development in this area, in my opinion, we would find all the answers for which we would need to make this possible.

A solution to colonizing a planet that is normally too hot and or exposed to excessive amounts of radiation (galactic /cosmic) is to use all of the natural occurrences already found on the moons of Saturn (Enceladus) we could use them to essentially cool down the dangerously hot temperatures of a planet like Venus and rebuild its atmosphere.

Some of the natural occurrences already existing on these moons of Saturn are Titan, with its abundance of natural resources and carbon compounds, and Enceladus with is Plumes coming from ice volcanoes. Through a process of freezing Venus' dense carbon dioxide atmosphere causing it to liquefy and fall to the surface, we would then replace the toxic atmosphere with gases emitted from these ice volcanoes consisting of important earth-like elements such as Nitrogen, methane, oxygen & ice particles while providing water & breathable oxygen to its new atmosphere. My proposal helps rectify the following issues pertaining to inhabiting Venus because of the following reasons: large amounts of surface heat caused from the planet's insulation effect and lack of protection from harmful radiation.

Surviving on a Moon Base

There are a handful of fundamental problems that we need to solve in order to survive on the moon. Among them are energy, habitat, transportation, economic development, and politics. These are discussed below, along with their potential solutions.

The two candidates for sustainable energy on the moon are solar and nuclear. They each have unique benefits and problems to overcome.

Solar Energy is a long-term solution in which the only cost after the initial production and placement is maintenance. This advantageous quality is one of the factors that makes it so appealing, since once the solution is implemented, minimal work has to be done (and minimal money spent) to keep it running.

Physicist David R. Criswell has researched and proposed how we can put solar receptors on the moon. His research involves using the moon receptors to beam power back to Earth, but we will focus on just the moon receptors themselves, and not the technology required and cost of receiving the microwaves on Earth, since that solves a different problem.

According to his research, the moon receives 13 petawatts of predictable solar power from the sun. By placing moon bases in optimal locations, we can harness on the order of 1% of that power, which is vastly more than enough to power colonies on the moon. In fact, that much energy would be enough to power 10 billion people living on Earth, which is why Criswell thinks this a viable alternative to fossil fuels.

The main factors influencing the cost of this plan are the cost of space access and the cost of transporting materials to the moon. Criswell believes that at least 90% of the machinery needed to build the moon bases can be built on site using lunar materials. This, along with the fact that solar panels can also largely be produced from the moon's regolith, heavily reduces transportation costs. For this plan to be feasible, we would need advances in technology that cheapen the cost of space access, which is currently estimated to be thousands of dollars per pound to orbit. Specifically, we require advances in propulsion and power technology.

It is estimated that the moon is impacted around 400 times a year by meteors. To protect the solar-powered moon base from them, I suggest we build the bulk of the base underground (in lunar lava tubes), with only the necessary equipment, e.g., the solar panels, vulnerable. There is research being done on deflecting dangerous NEOs from hitting Earth – we can use this technology to do the same for the solar panels on the moon. We need not worry about moonquakes or meteors that do not directly target the moon base, as they produce nearly undetectable ground motion.

A major challenge of solar energy on the moon is how to overcome the long lunar nights of 354 hours, or 14.75 earth days. Needless to say, solar panels need to be exposed to sunlight in order to gather energy, so placement of the panels is vital to how useful they will be. A simple solution is to place solar panels in several locations around the moon so that one is always in sunlight. This guarantees power will always be gathered, but there are other solutions that are just as effective and require less material. One such solution is to place the solar panels in “peaks of eternal light”, or locations that are constantly bathed in sunlight. There are a few possible places on the moon where this condition exists, one being the lunar north pole, specifically along the rim of the Peary crater. Placing a solar panel there is an obvious choice, and taking advantage of these peaks of eternal light seems like a great idea. A third location to place solar panels is in orbit around the moon. This technique has been studied since the early 1970's for usage on Earth, and it matches the collection period of panels in peaks of eternal light because of its consistent exposure to solar radiation. It also provides the advantage of being able to direct the energy gathered to a location that needs it most, including, possibly, Earth.

Nuclear Energy is another solution that has been considered to power colonies on the moon. A nuclear fission reactor may solely provide enough power to fulfill a moon base's power requirements. Scientists at the U.S. Department of Energy's Idaho National Laboratory have designed a miniature power station that could consistently generate 40 kW of power, enough for about eight houses on Earth. This device is quite versatile in its use due to its small size, durability, and lightweight. There is low risk in using it because its low power level would result in the reactor simply shutting down if the power failed. Bill Gates, who has invested in nuclear power, explains, “its [nuclear power] relative expense largely derives from building in safety features.” Since this smaller reactor is much safer than the enormous reactors we are used to, its cost should be greatly reduced. Larger nuclear power plants on the moon suffer from the same drawbacks as on Earth. Their high cost and potential danger increase the risk taken by implementing them, but, relative to solar power, they have a much higher payoff as well.

Nuclear power plants are noted for their resistance to environmental impacts and lower weight-to-capacity ratio when compared with solar plants. A nuclear power plant will always be smaller than a comparable solar power plant. In addition, nuclear power does not require sunlight to work, so the trouble of not having any power during the lunar night is completely avoided.

Since nuclear power can safely, reliably, and simply provide the energy needed for a small moon colony, I believe it is the superior choice of energy to start with. I would suggest bringing several of the suitcase sized fission reactors to the moon in order to give the power to the colony. However, the moon colony should also seek to use solar energy in the long run, because it will provide an incredible amount of free energy once implemented.

The kind of habitat in which moon inhabitants will live is another obstacle we need to overcome. We need to protect ourselves from the large temperature extremes observed on the moon due to the lack of atmosphere: -153 C to 123 C. We also need to shield ourselves from the cosmic radiation that is overwhelming present. Humans will need some sort of life support to supply a constant source of oxygen and other essential elements. How will we adapt to the moon's lower gravity, or can we simulate a stronger gravity somehow? Moon dust poses a significant problem as it can damage unprotected equipment, and may be toxic.

All of these problems are directly related to the habitat we build for ourselves on the moon. An obvious solution is to construct a surface colony, comparable to how we live on earth. The surface colony would need some sort of protective bubble that keeps radiation out and oxygen in. Perhaps there could be several distinct modules that serve as the protective bubble, and we would only live inside of these, instead of directly on the lunar regolith. We could cover these modules with lunar soil, or possibly build them out of “lunar bricks”, which are glass-like solids fused from lunar compounds. Regardless of the type of protection we give ourselves on a surface colony, this solution remains the easiest to build, but also the hardest to maintain and ensure safety of its inhabitants.

An alternative to the surface colony is the underground colony. While such a colony is complex to build, it immediately provides several benefits that surface colonies lack, such as protection against radiation, air leakage, and micrometeoroids. Extending this solution, we could live in lunar lava tubes, which are large hollowed out areas below the moon's surface that were formed billions of years ago. This reduces the complexity of excavation while still providing the benefits of living underground. These lunar lava tubes can serve as a shelter from the severe environments, including meteorites, high energy UV radiation, and extreme temperature variations. We know they are reliable as they have survived for billions of years so far. In addition, scientists have discovered that there are significant water deposits near some lava tubes, making this solution even more appealing. See Figure 8 for a diagram of a possible lunar lava tube.

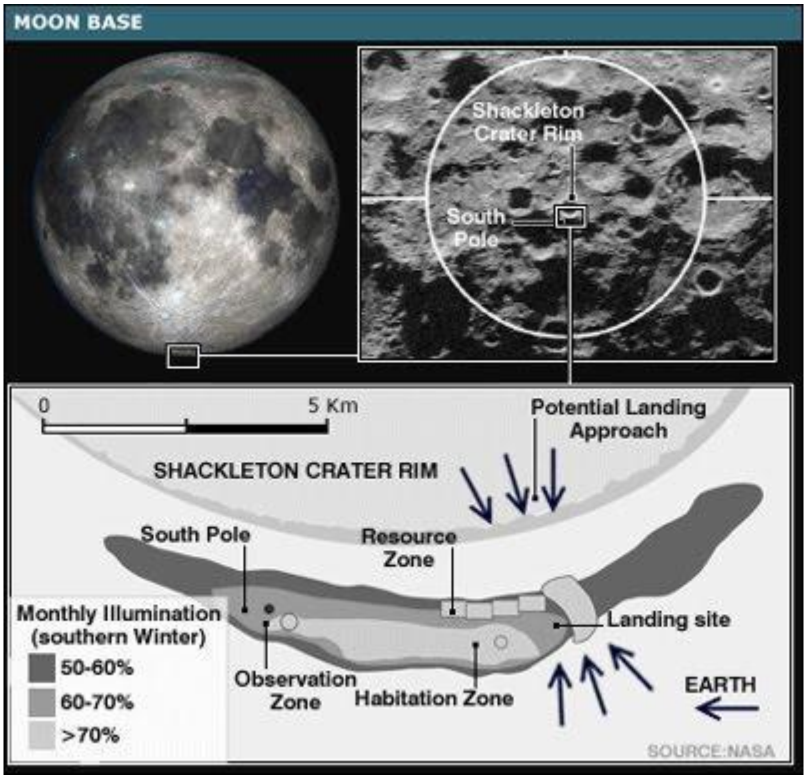

Fig. 8. Lunar Lava Tube in Shackleton Crater

Credit: http://spaceports.blogspot.com/2009/09/water-ice-and-lunar-lava-tube-nexus.html

The location of our colonies is just as important as its type. Ideally, such a location should be easily accessible (for when we expand), it should have features and objects of scientific interest, and there should be a secure deposit of natural resources nearby. There are three general places we can inhabit: the polar regions, the equatorial region, or the far side of the moon. Ideally we would find a lunar lava tube within the region we choose.

The north pole of the moon has a stable temperature of -50 C, similar to the Antarctic. This temperature is livable, albeit only with extreme caution. Living on the lunar north pole could put us close to solar panels, making energy transfer easy. Since we would be near Peary

Crater, we could choose a spot that has a good ratio of day to night time, making the adjustment to living on the moon a little easier. There are craters in the north pole that are potentially valuable for astronomical observation, and some may contain valuable concentrations of elements. However, there is a large inflow of solar winds at the north pole which would create damaging voltage differences. This is the choice that I suggest, because it has several helpful advantages, and the disadvantages could be mitigated by burying deep enough into the moon.

The equatorial region of the moon will likely have a high concentration of Helium-3 due to billions of years of solar winds bombarding the soil – some experts estimate millions of tons of Helium-3 in lunar soil. This element is much sought after for nuclear fusion research, and a single space shuttle load could power the entire US for a year.

The far side of the moon would serve as a very useful outpost for radio telescopes (because it is shielded from the earth) and optical telescopes. The far side is believed to have the highest concentrations of Helium-3 and other valuable elements because it is fully exposed to solar winds, unlike the near side.

The transportation on the moon is vital to survival there. Moon buggies have been tried and tested from the Apollo missions in the '60s and '70s. They are a doable mode of transportation, but are far from ideal. The reduced traction on the moon due to the lower gravity and the lunar soil increases the chances for the simple moon buggies to get stuck. Even if they do not get stuck, the reduced traction requires more power to get around. In addition, they kick up a lot of lunar dust, which is a bigger problem than it sounds. Moon buggies work well for transporting one or two astronauts and some gathered material to and from camp, but I do not think they will be the primary mode of transportation between space colonies.

A solution to both the lowered traction and the dust kick-up is to follow what we did on Earth: build roads. Roads would provide the necessary traction to get around easily and fuel-efficiently, and would let moon rovers travel at increased velocities. They would almost completely reduce the dust suspension, and are extremely flexible in terms of where we can build them and their direction. However, their major drawbacks are their enormous cost and difficulty to build. Building roads is not feasible when first developing a lunar colony, since the money and power needed could be spent on solutions to more serious problems. Constructing roads would need an alternative energy source to solar power due to the amount of power required. We should keep roads in mind, however, for when we are well established on the moon.

Using pressurized rovers is another possible solution for lunar travel. They would protect against radiation, and, if a life support system was implemented, could transport people without the need for space suits. Current ideas for pressurized rovers allows for two to four astronauts to live and work comfortably for up to 3 days. This machine is more suited for scientific missions, as opposed to other vehicles that have the sole purpose to transportation.

There has been research on vertical-take-off/landing flying vehicles that could be used on the moon. In fact, Bell Aerosystems actually proposed a design for the Lunar Flying Vehicle (LFV) to aid on the Apollo missions a few decades ago (see Figure 9). The LFV was the result of a year-long study that the company conducted. However, the concept was abandoned in favor of the lunar rover. Despite this, current technology could be used to design a superior machine, and, instead of being designed as a general transportation mechanism, could fill the niche of difficult-terrain-navigator. The largest drawback is the plethora of harmful lunar dust that vertical-take-off flying vehicles suspend. I am not sure how this can be avoided, but perhaps it would be less of an issue if isolated from the main colony. (One can imagine a situation in which a moon buggy would be used to travel to this aircraft, and then this aircraft used to travel much farther distances.)

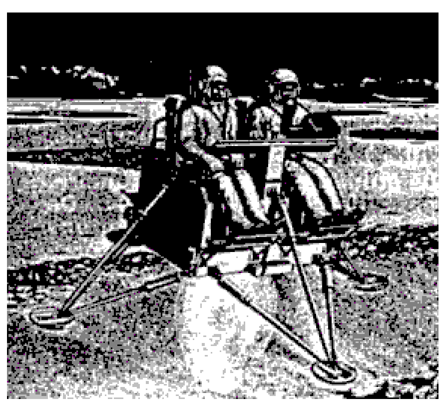

Fig. 9. Apollo FLV

Credit: Jean-Christophe Carbonel http://www.astronautix.com/craft/lfvbell.htm

A completely different kind of transportation, a lunar cable car/suspended monorail, seems feasible to me. See Figure 10. for an artist's rendition of a lunar cable car. This mode of transportation would be constructed similar to cable cars on Earth, but would be able to span vast distances on the moon at a reasonable cost. This is due to the lowered gravity and the absence of obstacles blocking the path of the cable car. Another benefit is the fact that the moving parts completely avoid contact with the lunar surface, thus eliminating all dust suspension.

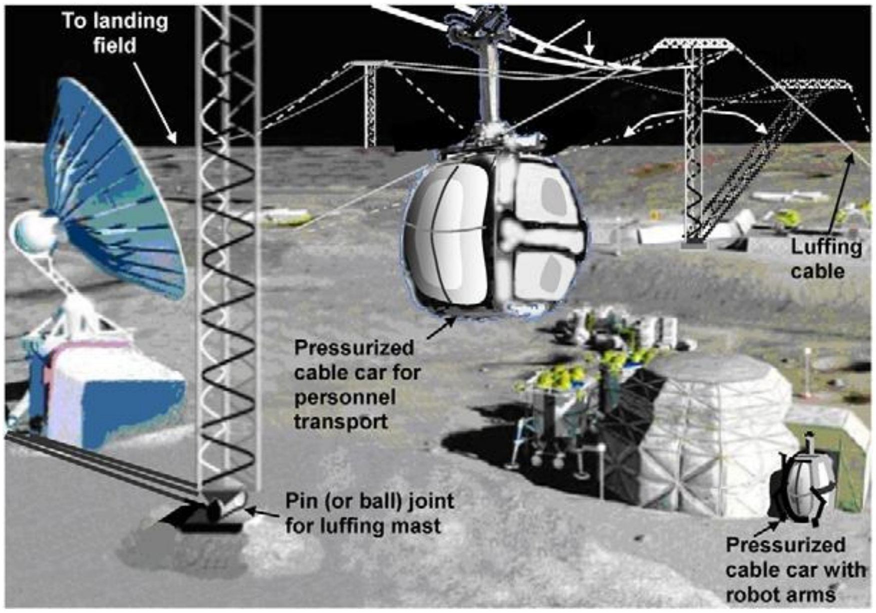

Fig. 10. Lunar Cable Car

Credit: http://www.universetoday.com/13216/building-a-base-on-the-moon-part-4-infrastructure-and-transportation/

Cables cars have been built on Earth in temperatures colder than -20 degrees Celsius, which is a testament to their reliability in extreme cold. The materials used to build cable cars would primarily, if not entirely, be found on the moon. I speculate that the roof of the cable car, as well as the stations through which the cable car passes, would have solar panels on them to help contribute to the 2 MW needed to power it. Due to the lack of drag on the moon, these lunar cable cars could be wide enough to hold dozens of people comfortably and still move at a quick pace.

Safety is a big concern when using cable cars. There have been several incidents around the globe where cable cars have gotten stuck or malfunctioned, resulting in fatalities. The cable cars on the moon would need their own life support system, and I would like to equip them with some sort of mechanism to prevent them from getting stuck in the middle of nowhere.

Specifically, we could attach wheels to the bottom of the car, and, in case of emergency, the car could release itself from the cable, fall to the ground (the specifics of falling safely would need to be worked out), and then be able to be driven to the nearest station.

An alternative to this is to have the cable cars on the surface, similar to a trolley, which would reduce the complexity and the cost, but would again introduce the problem of lunar dust. Each variation could be used for its own purpose.

This kind of transportation is very different from the others mentioned thus far because a cable car can only travel to predetermined destinations. It therefore suits a different purpose; lunar cable cars could be the primary transportation between lunar colonies, whereas wheeled vehicles would be more suited for exploration, or for traveling within lunar colonies, where there are variable paths to take.

The final mode of transportation I present is the railroad, another very feasible idea in my opinion. Railroads can be constructed from indigenous materials, and could even be constructed exactly where they will be placed, which is a nice alternative to having to transport the material from the moon colony to the construction site. There are two types of railroad that could be built, the conventional railroad (the one thought of “choo-choo”ing), and the MagLev, or magnetic levitation railroad.

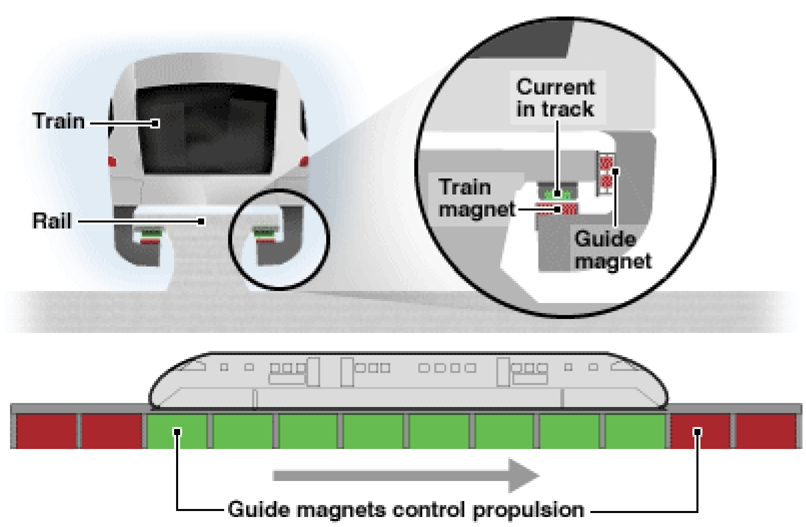

Fig. 11. MagLev Train

Credit:
http://newsimg.bbc.co.uk/media/images/42118000/gif/_42118168_maglev_train_inf416x260.gif

Conventional railroads would operate in a similar manner to how they operate on Earth, but there are complications introduced by having them on the moon. Due to the long lunar days and nights, how would we solve the problem of thermal expansion? Solutions include incorporating joints in the rail to allow for the expansion to occur, and permanently shading the rails so thermal expansion never occurs. Another problem is the fact that a derailment on the moon would almost always be fatal to passengers, so we would need to decrease the chance of that happening. The complexity of the problem is realized when trying to develop a system that both restricts the car from ever leaving the track (like the scheme roller coasters use) and also allows for easy track switching. Michael Thomas, Contributing Editor for Moon Miner's Manifesto, has elaborate solutions to this problem, including a flatbed quad-rail and a concave bed quad-rail, both of which introduce rails above the wheels to constrain the train's motion.

MagLev trains would be well suited for the moon due to the lack of atmospheric drag. We could build wide cabins that could transport travelers or materials without vibration at speeds comparable to aircraft on Earth. Because the moon is currently uncolonized, a great portion of the cost of building MagLev trains would be reduced since there is no need to deal with rights-of-way. Despite this price decrease, building a MagLev train would cost in the hundreds of millions per kilometer. To decrease the price further, we would need advancements in construction methods. Maintenance costs of MagLevs can be up to 90% cheaper than conventional trains due to the lower wear and stress on the rail.

Like lunar cable cars, railroads would only be able to travel to predetermined locations, and thus would only be useful for transporting people or materials from colony to colony, and not explore at all. The major advantage lunar railroads have over lunar cable cars is their velocity, which may make it worthwhile to build them. Perhaps we could even build them underground to reduce the effects of lunar dust and decrease the hazards they pose to civilians. David Schrunk, Madhu Thangavelu, Bonnie Cooper, and Burton Sharpe wrote a paper, "Physical Transportation on the Moon: The Lunar Railroad," about building railroads on the moon, which can serve as a starting point for more research.

Two more aspects we need to consider while planning to live on the moon is its economic development, and the politics involved.

Mining and refining the moon's materials on site may be advantageous both to construction there and exportation. For example, Helium-3 is thought to be abundant on the moon (compared to Earth), and could be sold at about $1500/g, which is 120 times pricier than gold. In addition, the lower gravity of the moon allows for unique material processing. We could manufacture “foaming metals”, in which a gas is inserted into a metal. This is impossible on Earth, but easily achievable on the Moon due to the lower gravity.

In colonizing the moon, we must be careful to respect other countries' space policies. The only comparable situation is sending people to the Antarctic, so it would be wise to study the effects that has had. In addition, it is essential that the colonization of the moon be a completely peaceful event. There are already huge risks in attempting this; we do not need other humans to pose a risk as well.

Chapter 3: Dealing with Radiation in Space Travel

Types of Radiation

When discussing any topic related to radiation, it is important to be able to distinguish the differences between the two major types, Ionizing and Nonionizing.

Ionization radiation is radiation that is made up with energy particles from which each particle carries enough energy to be able to strip electrons from orbiting atoms in space creating a set of charged particles. This type of energy is typically seen and generated through a few different ways.

The first can be seen when dealing with a now common nuclear reaction found in any nuclear reactor all across the world, because of their high temperatures from which are necessary in producing particles with such high energy. Another way for these high-energy particles to be created is with a particle accelerator. A particle accelerator (see Figure 12) is an instrument that contains high-speed particles in the form of well-defined beams that are generated through the use of electromagnetic fields (either electrostatic or oscillating fields). These fields are used to propel charged particles at high speeds so that they can eventually be controlled and formed into these high speed and well-defined beams. Also, this high energy can be created by the electromagnetic fields from the explosion of stars, resulting in the acceleration of charged particles.

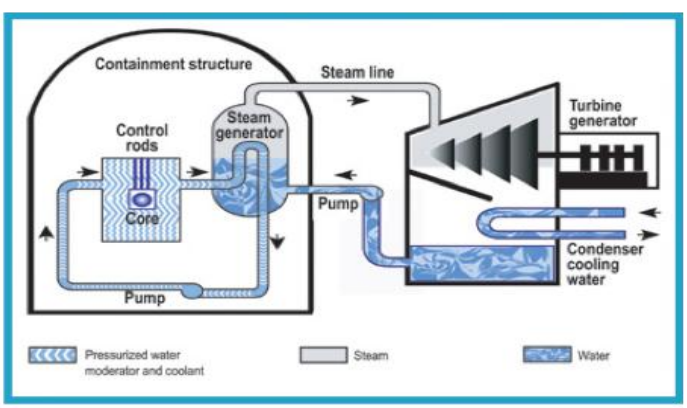

Fig. 12. Example of use of ionizing radiation in nuclear reactors

Credit: http://www.world-nuclear.org/how/npreactors.html

When ionizing radiation is emitted from an atom, it typically frees an electron from an atom orbiting close by; however, rather than just stripping electrons from an atom, this type of radiation can sometimes strip entire nuclei from other atoms. This action is responsible for the alterations of chemical bonds while also producing Ions (negatively charged electrons) in pairs referred to as ion pairs, which are known for their highly chemically reactive state. Because of these highly reactive particles, there is a significant increase in the total damage/unit energy of this type of radiation. Some examples of ionizing radiation are Cosmic rays, Alpha/Beta and Gamma rays. Ionizing radiation can be found everywhere in the Earth's environment and is more commonly found in areas containing naturally radioactive materials which may also be exposed to cosmic rays.

Although this form of radiation is found all over the earth's environment it can't be seen by the naked eye, and can only be seen using certain instruments like the Geiger Counters. These are types of particle detectors specifically used to detect and measure ionizing radiation that is produced in gases with low pressures. Ionization radiation has some positive effects on humans when exposure is controlled with special equipment (medical or scientific); otherwise, any exposure to ionizing radiation is deemed extremely harmful which can help shed light on the importance for astronauts finding ways to shield themselves from it.

The next major form a radiation is referred to as non-ionization radiation. Contrary to its counterpart ionizing radiation, this form of radiation relates to any form of electromagnetic radiation that does not carry enough energy/quantum to ionize an atom or molecule (fully strip/separate an electron from an atom or molecule). This type of radiation is responsible for the excitation or movement of an electron to a higher state of energy. Because of its tricky definition, radiation occurring with a particle that has less than 10 electron volts (eV) is considered to be non-ionizing and anything greater is considered ionizing radiation. Because of the filtration of radiation through most of the oxygen gases along with others, the remaining radiation emitting from the sun is located in the non-ionizing band that is responsible for causing molecular damage from the particles that do not ionize. One example of its effect on humans is a form of molecular damage called sunburns.

Radiation threats

Radiation poses a threat to mankind everywhere including on earth as well as in space; however, because of Earth's very strong Magnetic field this threat is not seen by everyone on earth. With mankind seeking to extend the survival of its species by colonizing another planet along with trying to discover new areas of space, one question or topic troubling mankind is the question of how we can understand radiation enough to develop technology capable of shielding humans, space shuttles and eventually life on another planet. When speaking about radiation, it's important to understand that in its basic form it has to do with the movement of energy and/or matter through space, of which any heated body can produce. Also, this movement of energy comes in many varieties and strengths depending on the frequency of the waves (long/slower or short/faster). An example of a form of radiation is sunlight emitted from the Sun as electromagnetic radiation. Similar to sunlight being produced by the sun, there are a number of other types of radiation including the following: Gamma and X-ray radiation (the most severe/deadly), which occur in higher levels and are projected as Ultraviolet or visible light; Neutron radiation consisting of Neutron particles (neither positively or negatively charged) emit a wide range of Energy at a variety of intensity levels; and Alpha and Beta Particles (negatively charged electrons/harder to shield from) that are produced from the collision of cosmic rays and any molecule found either in space or in an atmosphere. The types of radiation that pose the biggest threat to space travel for humans are cosmic rays and gamma radiation. Therefore when looking for ways to shield from them there are a few things to keep in mind such as strength of material, thermal properties, resistance to damage and cost efficiency. In calculating the correct amount of a material that should be used to successfully block radiation, we can look to use the following equations:

- Half Value Layer: $HVL = (Ln*2)/\mu$; μ = linear attenuation coefficient
- Tenth Value Layer: $1\ TVL = 3.32*HVL$

Continuing on with the different types of radiation, I'd like to focus on what to look for in trying to shield from each of these different types. First, when talking about Gamma and X-ray shielding, it's ideal to use materials that have a higher density because this property alone slows the intensity of this radiation. While high density materials are preferred, these typically add a substantial amount of weight which brings up the issue on the total weight allowed for space shuttles for efficient travel, makes the use of lower density materials more appealing while increasing the width or thickness can actually changes its effectiveness. The best material for shielding gamma / X-rays is lead because of its high density and atomic mass number. When dealing with Alpha and Beta radiation, the thickness of a material is not as important as with gamma and X-ray exposure because essentially a piece of paper ½" thick or an even plastic only a few cm thick can serve a successful shield. Beta Particles are viewed as more difficult to shield against because as they interact with another material. They produce what's called "secondary radiation", which is caused when photons are created by the action of a primary radiation source on matter such as secondary electrons and secondary cosmic rays. This secondary radiation occurs when beta particles pass through elements that have a high atomic mass and density (like lead). This suggests that the use of high-density plastics can be an effective barrier against high-energy beta radiation and one example of a type of high density plastic for which NASA plans to use is a type of hydrocarbon called Polyethylene.

Contrary to gamma radiation, lower density elements are more effective against shielding from neutron radiation because they would prevent these neutrons from being able simply pass through them like with higher density elements and also that they possess a higher probability of forming cross-sections able to interact with the neutrons. A specific molecule for which can successfully serve as efficient shielding material is a primary hydrogen-based material because the higher the concentration of hydrogen atoms that are present in these materials, the more protection it will provide and on a final note, hydrogen based materials are fairly inexpensive to create which can suggest an interest using materials with a large hydrogen atom composition.

This brief explanation of the different types of radiation existing in space and the specific properties a material should possess in acting as an effective shield is that it's not entirely based on one particular attribute like the thickness or density of a material. When trying to find a successful way to shield from radiation, it's important to understand what types of radiation will be present because this directly affects whether we can use certain materials or not while also determining the correct dimensions of a material. In the comparison of a materials density composition it's important to understand fully how each type of radiation reacts with certain materials.

What makes radiation such a big threat while traveling in space, is that there isn't a constant flow of it at any particular point in time; however we do know that solar activity runs on a consistent time scale averaging around every 11 years and repeating, This time scale is commonly referred to as the Solar cycle or "Sunspot cycle", which specifically, is used to measure the amount of magnetic flux that rises up to and is projected on the Sun's surface as sun spots. In this solar cycle there are two areas of importance with regards to harmful levels of Galactic Cosmic radiation are called the solar minimum and maximum. As you might be able to guess, from a space exploration standpoint it would be the most ideal to travel in space at a time when the levels of radiation are low as to reduce the overall radiation exposure to the shuttle and its crew. Another reason why traveling at a time during the solar minimum is ideal because during this period we can use materials found on earth with the capability of shielding radiation like the use of a high density plastic – polyethylene.

With a lack of a protective magnetic field in space like on Earth, humans are very susceptible to radiation. The SI unit for measuring equivalent radiation damage from absorption is in Sieverts (Sv), which is defined as the absorption of one joule of energy by one kilogram of matter (in this case human tissue). Many radiation levels can also be expressed in terms of the common unit rm (rem), and 1 Sv = 100 rm. Any exposure of radiation greater than 8 Sv would be fatal within 2-4 days and cannot be treated. If a human is on a spacecraft in space, the exposure from a solar flare or CME could be fatal. A CME on average releases 10^6 joules of energy, which would be significantly past the lethal limit of radiation exposure for a human. The radiation emitted from a CME heading towards earth could be as high as tens of a Sievert, which would be fatal. In the Apollo era, astronauts spent less than two weeks in space. NASA's current guidelines set a career gap on radiation exposure for astronauts so that less than a 3% increase in the risk of death from cancer is the limit. The maximum limits for 30-year-old astronauts are 54 days for females and 91 days for males. The maximum limits for 55-year-old astronauts are 159 days for females and 268 days for males. One question that you might ask is why are women, on average, more susceptible to radiation damage than men? Recent studies performed by the New York State Department of Health have shown that in women, the risk of breast and ovarian cancer from radiation is very high. Compared to men, there has been no clear evidence that prostate cancer can be caused by radiation. It has also been observed that females have more radiation induced thyroid cancer than males. This makes sense to me biologically, because the female sex organs are much more susceptible to GCR particles from radiation than the male sex organs. This is primarily due to the larger surface areas in females sex organs. Breast cancer also has much higher occurrences in women than prostate cancer is in men on average. As an eager human race trying to colonize parts of space in the next 50 years, I believe we want to limit as much radiation exposure as possible. One way we can do this is to calculate the shortest distance between Earth and Mars and travel during that time.

While doing this, it is important to make sure the period at which we depart Earth or traveling from Mars does not occur during a CME. We would need to predict when a CME occurs using the Sun’s 11-year cyclic period of sunspots to track when the next CME will occur.

What are the ideal properties of a material that protects against radiation? The ideal material to be used for radiation protection/shielding would be one that has both lightweight properties and as well good deflection properties against radiation particles. A material such as a hydrocarbon has both of these properties. We want a material that is light enough to be made for a spacecraft and we also want it to minimize the highest amount of radiation exposure as possible. Hydrocarbon polymers such as polyethylene have these important properties that would be the most desirable material to use in making part of the hull on a spacecraft. Materials that just contain carbon, such as fullerenes and buckminsterfullerene (C60), can also be very efficient in shielding against GCR particles in radiation. I believe the use of these types of materials is critical to our success in successfully protecting humans against radiation when space travel becomes more prevalent in deep space within the next 50 years.

How much Radiation is in Space

Galactic Radiation

What is Galactic radiation? Galactic radiation is, one of a few different types of radiation, made up of cosmic rays that originate from outer space and distant galaxies. Galactic Cosmic Rays (GCR) are energetic particles that have the ability to produce secondary particles, which are created within one degree of its primary particle that travel down to the earth’s surface. A cosmic rays’ exact origin is unknown because of the countless magnetic fields located on or around just about every celestial object in space and their ability to bend cosmic rays in random directions. Due to a magnetic field’s manipulation of approaching cosmic rays, this makes it nearly impossible for scientists to pinpoint the exact place from which these rays come from.

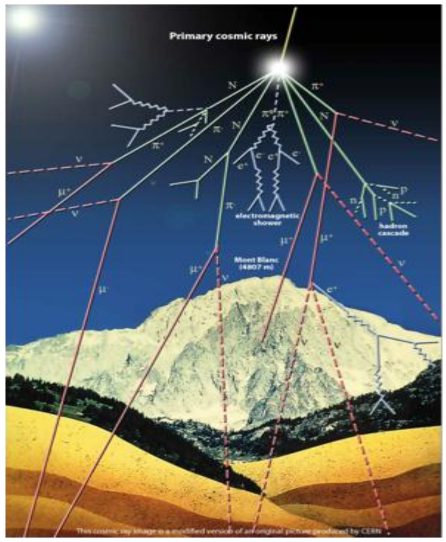

Fig. 13. Collision of a primary cosmic ray with molecules in atmosphere

Credit: http://www.scifun.ed.ac.uk/card/images/left/cosmic-rays.jpg

All Cosmic rays consist of a variety of different particles and nuclei. Approximately, cosmic rays are consisting of about 89% protons and Hydrogen nuclei, roughly 10% Helium Nuclei and Alpha/Beta particles, and the remaining 1% consists of nuclei of heavier elements along with solitary electrons. Because of the large variety of energy particles, this suggests a wide range of places from which these particles could come from. This range includes processes of the sun (along with other stars) and stretches out to the unknown thermal mechanisms existing in the farthest parts of the known and visible universe-which includes such topics as *collective acceleration*. Collective acceleration is the use of a high-current, moderate energy electron beam to generate a lower current, high-energy beam. This two-step process starts when a wave is grown on an electron beam by means of an interaction between the electron beam and some external structures such as loaded waveguides or a tape helix. The beam is then extracted from the wave growth region and inserted into the inhomogeneous drift region where the phase velocity of the wave is increased in a controlled fashion. This is because the initially trapped particles will continue to be trapped and accelerated with wave.

Cosmic radiation has been proven to account for nearly 10-15% of the earth's natural background radiation. Natural background radiation is the type of ionizing radiation that is continuously seen and emitted by natural and artificial sources throughout Earth's environment. At higher altitudes cosmic radiation is roughly 7x more harmful to humans located anywhere above sea level. As these cosmic rays travel down through the earth's atmosphere the charged particles lose some of their energy. Therefore, it makes sense to say that if the surface is located at a distance higher up in the earth's atmosphere that the energy in these particles would be greater than those at lower altitudes, and thus can cause more harm to humans.

Distance between Earth and Mars

To understand the correct distance between Earth and Mars, it's helpful to understand that it changes every day and gets closer and or farther apart each day depending on where exactly each planet is on their respective orbits. On average, when Earth is at its furthest distance from mars, meaning that it lies on the opposite side of the Sun, it's about 401 million kilometers from Mars. However, when Earth and Mars are both at their furthest position on each of their own individual planetary orbits from the sun this is referred to as Mars and Earth being at Aphelion, of which on average the distance between the two planets is 225 million km. Contrary to being at their furthest positions from the sun, when they are at their closest to one another this referred to as them being in opposition. This means that as Earth is at the furthest point from the sun (earth's Aphelion) and when Mars is at its closest distance to the sun (Mars' Perihelion) at the same time that the two planets will be at their closest distance to one another, which in 2003 was recorded at 56 million km was the closest distance ever recorded. This close distance occurs every two years where the distance gets closer for a span of 15-18 years until it repeats. The next time where earth and Mars will be at their closest distance before the cycle repeats is expected to take place in 2018 at 57.6 million km (~35.8 million miles).

To calculate how long a trip from earth to mars would take using their average distance measurement recorded (140 million miles), while traveling at a speed of approximately 24790 mph (594,960 miles per day), it would take about 8.4 months (235.2 days). This means that it will take 8.4 months to get from earth to mars if we travel at the time when they are the closest to one another meaning that it is very important to plan missions to Mars at their closest distance because at any point after that our flight time would be significantly increased hence our total time of exposure to radiation in space would also increase making the mission a potential failure. Below is a list of dates and approximate distances of the optimal times for a mission to Mars to take place (see Figure 14):

- Dec. 24, 2007 – 54.8 mil. miles
- Jan. 29, 2010 – 61.7 mil. miles
- Mar. 03, 2012 – 62.6 mil. miles

- Apr. 08, 2014 – 57.4 mil. miles
- May 22, 2016 – 46.8 mil. miles
- July 27, 2018 – 35.8 mil. miles
- Oct. 13, 2020 – 38.6 mil. miles

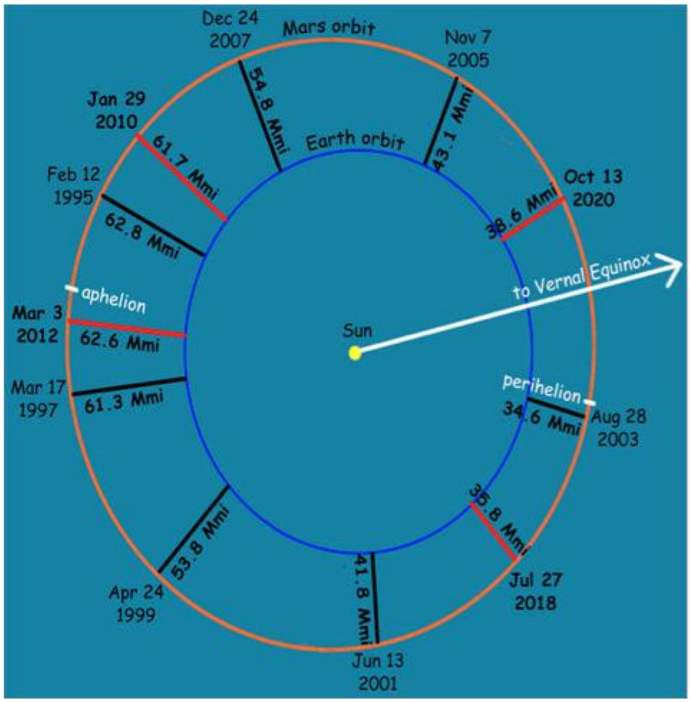

Fig.14. Earth and Mars close approaching dates and measurements up to 2020 (million miles)

Credit: http://cseligman.com/text/planets/marsoppositions.htm

Mars Radiation Experiment (MARIE)

As part of the 2001 Mars Odyssey spacecraft, the Martian Radiation Experiment (MARIE) successfully sampled the radiation present in space en route to Mars and in orbit around Mars. The data collected allows us to be optimistic regarding a manned mission to the red planet:

Shielding Condition	GCR Dose Equivalent Rate (Sv/year, solar max)	GCR Dose Equivalent Rate (Sv/year, solar min)
Interplanetary Space	0.21 (0.28)*	1.07 (0.73)
Interplanetary space with 10 g/cm^2 Al	0.20 (0.24)	0.85 (0.59)
Surface of Mars (16 g/cm^2 CO_2)	0.08	0.33
Surface of Mars (16 g/cm^2 CO_2 + 20 g/cm^2 regolith)	0.07	0.26

*Values in parentheses are from Borggrafe et al. 2009, and illustrate variations due to different versions of computer code used for modeling.

Table 2. Estimated radiation levels in space based on MARIE

Credit: http://journalofcosmology.com/Mars124.html

Note that the most recent estimates based on MARIE's data are the ones in parentheses from Borggrafe et al. 2009, so we will use those values in our computations.

According to the table above, the mean (averaging the solar max and solar min data) annual dose equivalent rate from GCR is .505 Sv/yr, or 1.38 mSv/day. The use of the mean is for convenience; a mission plan would have to take into account fatal spikes of GCR instead of averaging the data.

Considering the allowed career maximum equivalent dose of 1 Sv, an average dose equivalent rate during interplanetary travel of 1.38 mSv/day allows us to say with confidence that a flight to Mars is plausible in terms of radiation absorption. For example, given a twelve month round-trip flight to Mars (six months each way), astronauts on board would be exposed to a total dose equivalence of roughly .5 Sv. This allows the astronauts an extended stay on Mars, as the radiation on the surface is less than that in interplanetary space. In fact, according to the data gathered by MARIE, the dose rate in orbit around Mars averages at 2 mSv/day (see Figure 15).

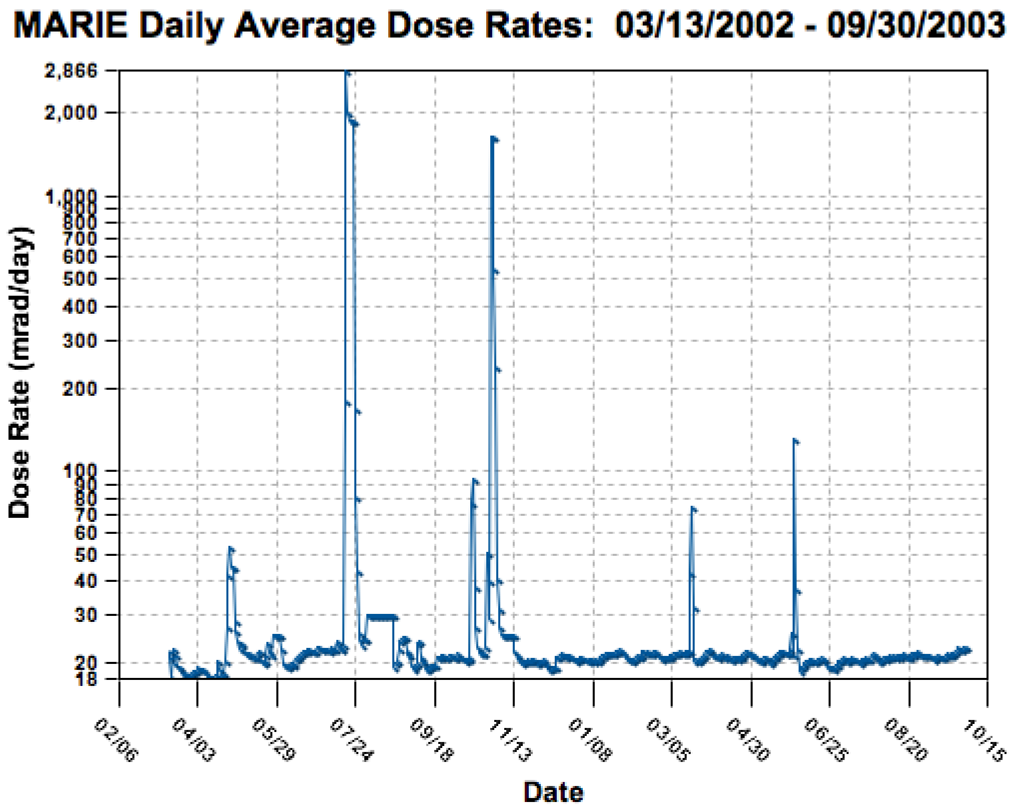

Fig. 15. Dose Rates in Martian Orbit gathered by MARIE

Credit: http://en.wikipedia.org/wiki/File:MARIEdoserates.nasa.png (http://marie.jsc.nasa.gov/Data/)

Note that 100 rad = 1Gy, thus 20 mrad/day = .2 mGy/day. To convert from grays to Sieverts, we realize that the composition of GCRs are 89% energetic protons, which have a factor dose of 10. Thus, when dealing with energetic protons, 1 Gy is about 10 Sv. This lets us interpret the average dose rate around Mars from the MARIE data as 2 mSv/day.

This lower equivalent dose rate compared to the interplanetary equivalent dose rate is due to Mars' atmosphere. The equivalent dose rate on the surface of the planet is likely even less than 2 mSv/day, given the increased protection from the atmosphere there.

This average equivalent dose rate allows astronauts to stay on Mars for (.5 Sv / (2 mSv/day)) = 250 days without exceeding the career allowed equivalent dose.

However, given the frequency of SPEs detected by MARIE (the six spikes of radiation in Figure 15), we must assume the astronauts will experience them during the travel to Mars and on the surface itself. It is these spikes of radiation that pose the greatest threat to astronauts, as they can be more than 100 times greater in dose than the average. We address this problem in later sections when discussing materials and the use of NEOs.

Curiosity's Radiation Assessment Detector (RAD)

Similarly to MARIE, NASA's rover Curiosity contains a Radiation Assessment Detector (RAD) to gather radiation information about the environment it is subjected to: Mars and the interplanetary space on the way to Mars.

NASA published preliminary observations from RAD which, like the data from MARIE, helps mitigate radiation worries about a manned mission to Mars:

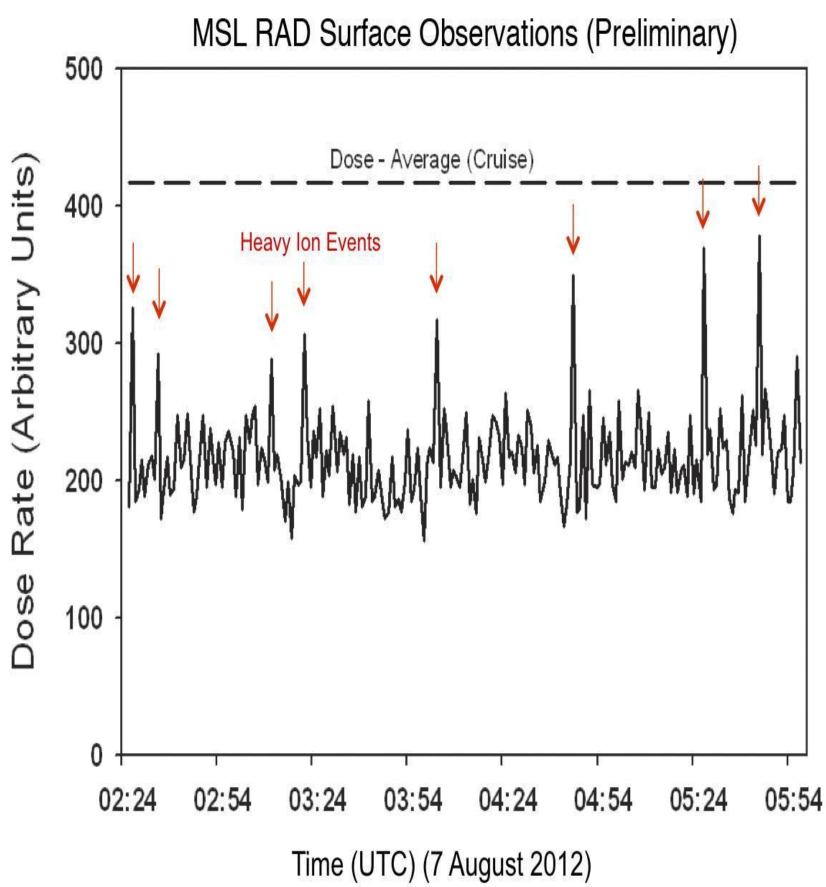

Fig. 16. Preliminary radiation data gathered from Curiosity's RAD.
Credit: NASA/JPL-Caltech/SWRI
(http://mars.jpl.nasa.gov/msl/multimedia/images/?ImageID=4338)

Although the data gathered do not provide any numerical comfort, they confirm that the dose rate on the Martian surface is about half that of the dose rate in space en route to Mars. This agrees with the data gathered by MARIE. The data also reveal that there are several spikes of heavy ion particles throughout the day that astronauts would be exposed to. These spikes are not the same as the ones seen in Figure 15, since these are seen on an hourly basis, whereas the ones in Figure 15 are seen on a monthly basis, are much more extreme, and last up to days.

Mike Wall, a SPACE.com Senior Writer, reports that the data from Curiosity show, “explorers would likely get around 1.9 millisieverts per day (.69 Sv/yr) during the flight.” While this number is an increase of 38% compared to the calculated 1.38 mSv/day based off the data from MARIE, it still allows for (1-.69 Sv/yr)/(2 mSv/day) = 155 days spent on Mars, a time period long enough for an initial manned mission. (This was calculated assuming an astronaut can be exposed to no more than 1 Sv, the lower end of the career maximum set by NASA, during the trip.)

Conclusion

The threat of radiation in interplanetary space was once believed to be fatal and unavoidable. Research has shown that while this can be true in certain circumstances (such as during a SPE), on average, the radiation will not prevent astronauts from making the flight to Mars and other destinations reachable in 6-8 months (assuming astronauts should not be exposed to more than 1 Sv during the round trip).

However, it is highly likely that during such a lengthy trip, the spaceship would be exposed to dangerously high levels of radiation from SPEs or other bursts that can threaten the astronauts’ lives. We need to either avoid these bursts, which is unlikely given the current propulsion and radiation detection technologies, or devise a method of protection that allows humans to withstand them with negligible effects. Possible solutions for protection that we have explored are radiation blocking materials, and the use of NEOs as a vehicle for interplanetary travel.

Materials used to protect/shield against radiation

We want a material that minimizes as much radiation exposure as possible and is light enough to be used on a spacecraft. The ideal type of material used for radiation protection/shielding would be one that has both lightweight properties as well as good deflection properties against radiation particles. A material such as a hydrocarbon (a molecule containing only hydrogen and carbon atoms) has both of these properties. Materials that just contain carbon, such as fullerenes and buckminsterfullerene (C60), can also be very efficient in shielding against GCR particles in radiation.

C60 (Buckminsterfullerene)

Buckminsterfullerene, otherwise known as “buckyballs” or C60, are large spherical molecules containing sixty carbon atoms bonded to each other (see Figure 17). One buckyball is about 1 nanometer (nm) in size and is 0.14 nm in average bond length. They are the largest known molecules in space and are three times larger than water molecules. They were first discovered in space in the planetary nebula IC-1, which is 6,500 light-years away from Earth.

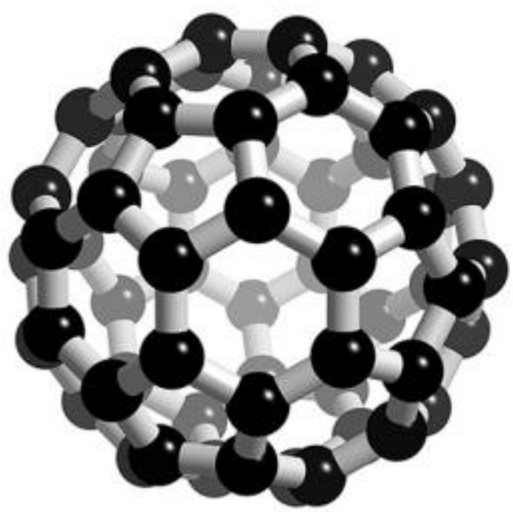

Fig. 17. A molecule of Buckminsterfullerene (C60). 60 carbon atoms are attached together. Credit: http://c60antiaging.com/c60-faq/how-does-c60-work-as-an-antioxidant/

Some of the properties of C60 that are important to our interest in using them as radiation-protective materials are their strong physical properties. They are very stable molecules and are resistant to both interstellar ultraviolet radiation and gamma radiation. Once formed, they have long lifetimes in space. Buckyballs have shown to maintain the annual recommended dosage of cosmic radiation (0.0024 Sv) using several inches of the material. A dosage of 0.0024 Sv is the annual dosage that most humans can be exposed to on Earth. It is critical that we maintain this in the spacecrafts that humans will be riding in the future. A molecule of C60 has a density of 1.65 g/cm3 per mol and has a molecular weight of 720.64 g/mol. Aluminum is the standard material used today for constructing the hull of many spacecrafts and has a density of 2.7 g/cm3 per mol. Compared to aluminum, C60 has better radiation protective properties and could possibly only require about 2 inches to be made in the hull of spacecrafts. This is less than the amount that aluminum is constructed on modern spacecrafts. C60 does not just have useful properties as a shield against radiation, but it also has promising uses as an antioxidant

An experiment that was conducted in the past year has shown that C60 can double the lifespan of rats if administered orally in olive oil. Rats that were administered 40 mg of C60 in olive oil for two weeks were assigned to the experimental group, and rats that were administered olive oil and water were in two different control groups. All groups were subjected to deadly gamma radiation after two weeks of administration of the different liquids. The rats that were given C60 in their olive oil lasted for 3 times longer on average than the rats that were given only water (see Figure 18).

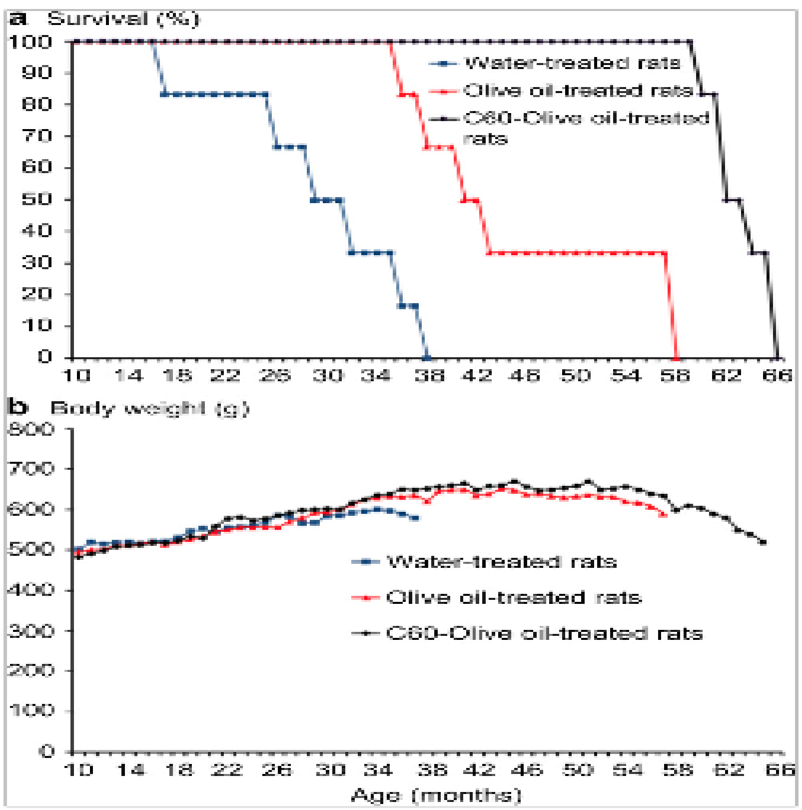

Fig. 18. Rat survival and growth. Effects of C60 in rats. (a) Survival and (b) growth of surviving rats.

Credit: http://www.owndoc.com/pdf/C60-Fullerene.pdf

This data shows that C60 could have very potential benefits if used as both an antioxidant drug and a shield against gamma radiation. I believe more tests should be done on this molecule and it definitely should be thought more highly of as a feasible molecule to protect against radiation. Its versatile uses as a medicinal drug and a shield against radiation prove it to be a very promising molecule that humans need to invest more research in. I believe that many organizations such as NASA could benefit from progressing this research more forward and determining its uses in the future to protect humans against radiation.

Polyethylene (Demron)

Polyethylene, the most common plastic used for commercial products, is a chemically synthesized polymer that is good at shielding against radiation. This is due to its high hydrogen content since hydrogen atoms are good at absorbing radiation.

Demron is a proprietary radiation blocking fabric with results comparable to lead. While the exact composition of the non-toxic polymer is unknown to the public, Radiation Shield Technologies, the company producing it, has divulged that it is essentially polyethylene between two layers of fabric. Because of this, Demron remains lightweight and flexible and can essentially be treated like a fabric for cleaning, storage, and disposal purposes.

H. W. Friedman and M. S. Singh of Lawrence Livermore National Laboratory (on behalf of the US Department of Energy) have measured the shielding properties of Demron by request from Radiation Shield Technologies. The results they found give hope that Demron, and other polyethylene based materials, can successfully be used to protect space-going astronauts from the previously discussed radiation threats.

Friedman and Singh experimented with different types of radiation, including beta (Figure 19), moderate-energy gamma (Figure 20), and high-energy gamma (Figure 21). Two samples of Demron, denoted as Mat 1, Mat 2, or Special material in the following figures, are compared with other materials in terms of how much radiation they prevent from transmitting. While lead is not being explicitly compared to Demron in this experiment, tantalum, an element very comparable to lead in terms of radiation prevention, is.

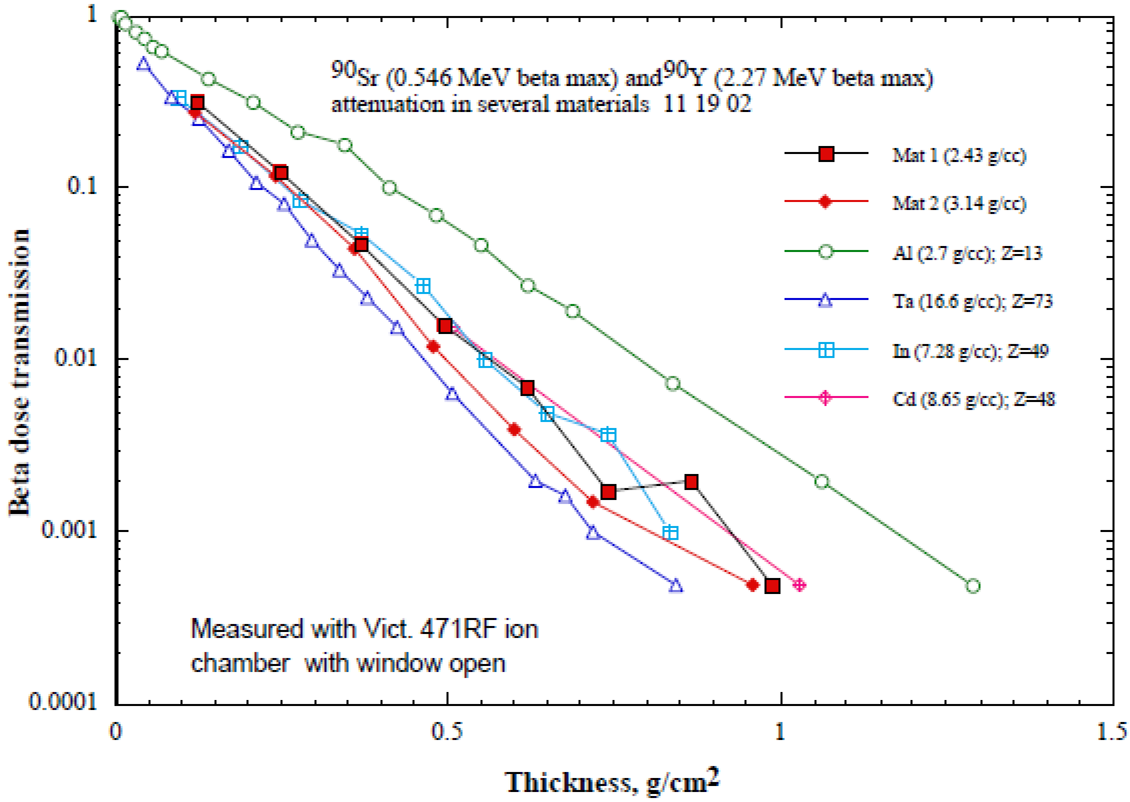

Fig. 19. Transmission of beta radiation through Demron and other materials. Credit: Friedman and Singh

The samples of Demron, Mat 1 and Mat 2, perform slightly worse than tantalum in preventing beta radiation from transmitting. They perform better than indium.

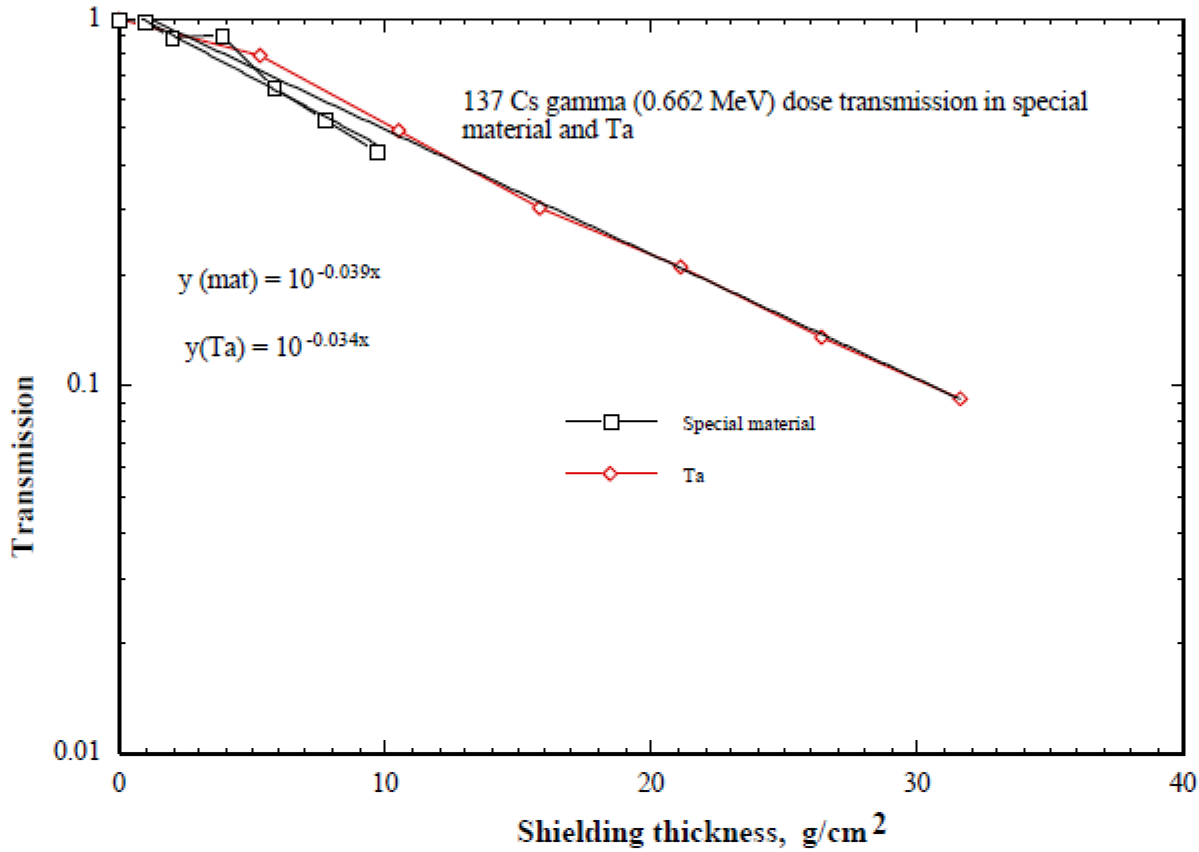

Fig. 20. Transmission of moderate-energy gamma radiation through Demron and tantalum. Credit: Friedman and Singh

Demron performs better than tantalum in preventing moderate-energy gamma transmissions in this experiment. Friedman and Singh suggest that a thickness of 2.7 cm (72 layers) and 29 cm (240 layers) of Demron would be required for a two factor and ten factor reduction in transmission, respectively. Their two suggestions are puzzling, however, since the thicknesses given divided by the number of respective layers does not result in the same thickness per layer.

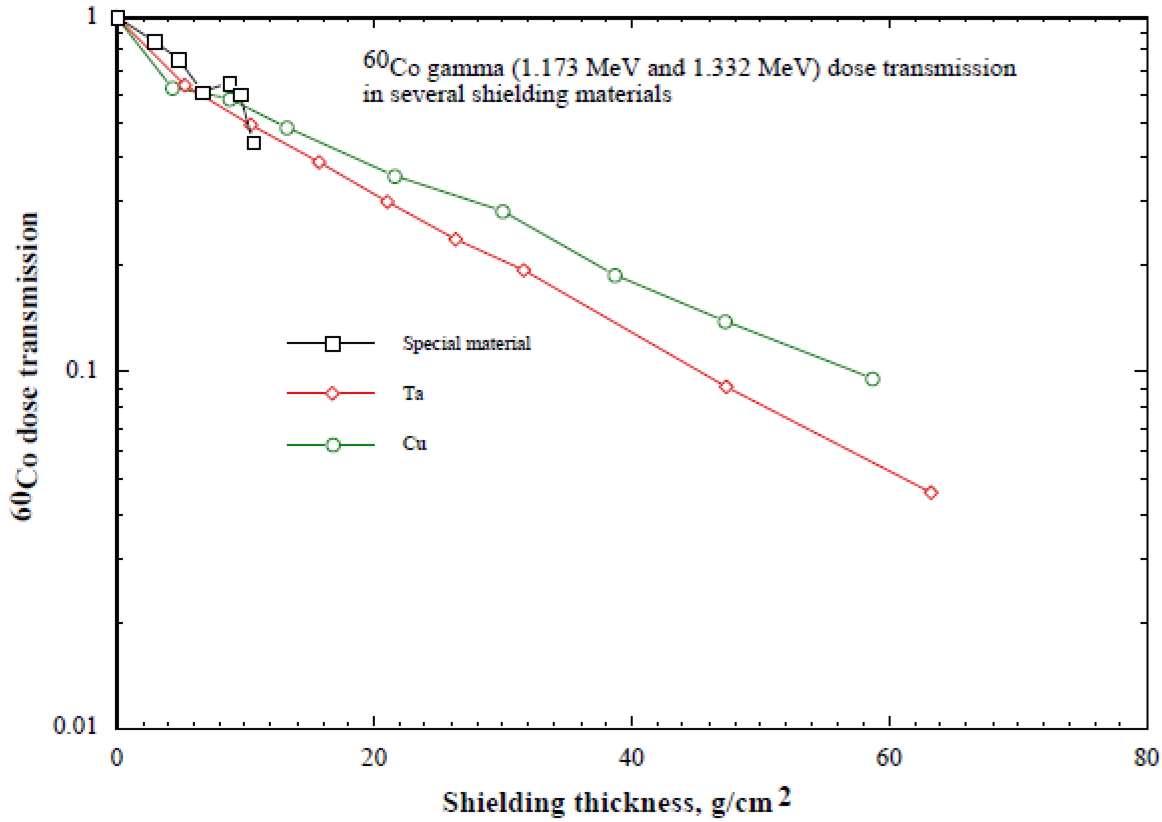

Fig. 21. Transmission of high-energy gamma radiation through Demron, Ta, and Cu. Credit: Friedman and Singh

For the samples given, Demron is comparable to tantalum in the prevention of high-energy gamma radiation transmission. According to Friedman and Singh, roughly 4.4cm (115 layers) of Demron is required for a factor of two reduction in transmission. They suggest that almost 383 layers would be required for a reduction by a factor of ten. I cannot compute how thick that would be due to the previous discrepancy regarding Demron's thickness per layer.

I would like to see this experiment repeated with much thicker samples of Demron so we could determine if the material remains comparable to tantalum when reducing the high-energy gamma transmissions by a factor of 100 and more.

Although Demron does not shield significantly better than lead by weight, the fact that it is non-toxic and contains no risk to the user gives rise for its use on board a spacecraft and even within spacesuits. However, my initial optimism for the material being a panacea has faded, as the results of the experiment have shown that although Demron is much thinner and more flexible than lead, much larger quantities of it are needed to have the same effect as a small quantity of lead. For example, 4.4 cm of Demron is required to halve high-energy gamma transmission, whereas only 1 cm of lead would be needed. In addition, further research has to be done to determine how long Demron can be used to protect against radiation before losing effectiveness.

Boron Nitride Nanotubes

Boron Nitride Nanotubes (BNNTs) have been an increasingly interesting subject of research due to their unique combination of properties and their wide array of potential applications. One such property, which stems from Boron's light nucleus, is their ability to absorb harmful neutrons in secondary radiation. This property is absent in the heavier elements that are commonly used to protect against radiation. Thus, including BNNTs in the development of a space shuttle could be a viable option to further decrease the harm of radiation exposure.

When BNNTs were first theorized, the technology to synthesize them did not exist. However, within the past few years, there have been laudable advancements in the synthesis process. As we continue to study this nanomaterial, we should keep in mind its potential for helping protect against radiation, as it may be fundamental to space exploration.

Electrostatic Shielding and Carbon Nanotubes

The use of conductive materials can be very beneficial to shield humans from radiation. In particular, materials such as carbon nanotubes (CNTs) can conduct enough energy to generate an electrostatic shield. CNTs can be semiconducting or semimetallic depending on the chirality of the material, the diameter and the number of walls in the tube. We can detect the X-rays that solar particle events (SPEs) give off early and activate the electrostatic shield. It can then be used as defense for when the heavier elements of an SPE finally reach the shuttle (minutes to hours later). On a regular spacecraft, it would take several feet of carbon nanotubes to generate enough energy to generate an electrostatic shield.

Electrostatic radiation shielding prevents ions from hitting the spacecraft during a trip across space. The biological effects of long duration exposure to space radiation is dramatically reduced (~ 70 %) for galactic cosmic rays (GCR) and for SPEs. According to current research, I believe that one of the best methods for radiation protection and shielding for long duration human missions is to use electrostatic active radiation shielding that is generated from carbon nanotubes (Adv. Space Res. 42 (2008) 1043).

NEOs

NEO Plan for Earth/Mars and Mars/Earth Travel

On the topic of traveling through deep space, one way humanity can safely travel through deep space and to another planet is through the use of NEOs. In using NEOs to travel from Earth to a planet like Mars, we focused on looking for a way to make this deep space mission feasible and less hazardous. With this topic of deep space travel comes the risk of being exposed to potentially life threatening levels of radiation. This threat of radiation exposure during a deep space mission inspired our plan of using NEOs to minimize this risk. The use of NEOs would mainly consist of using them as a means of transportation in which we would essentially hitch a ride on one or more of these NEOs (of which there is no shortage of while there is an increasing number of NEOs found each year) that surround earth. We propose that if we can successfully land our space shuttle on these NEOs, we can use their natural orbits to take us close to or in some cases directly toward a planet like Mars which had been deemed unreachable for manned missions in space. This idea would be very beneficial for humanity because through the use of these Near Earth Objects we would be able to put humans in space in areas that would otherwise be deemed deadly due to the severe amounts of radiation that could exist at any time throughout their mission.

This is made possible due to each asteroid having their own orbital paths that can be monitored and calculated using already developed and enhanced equipment such as the "new error model-which uses star catalog debiasing and an error model with assumed astrometric errors, cited by NEODyS-2. With the help of the ESA's (European Space Agency) sponsored NEO database, our group has developed a feasible idea for the proper use of NEO's to get from Mars to Earth and back with respect to the risk of radiation exposure (manned crew/ shuttle) through the use of robotic excavation and the analysis of particular target asteroids and their orbits.

To kick off this idea we must define the first major quality an asteroid must have in order to be considered a "target asteroid" for our manned mission to Mars. An NEO that at some point during its Orbital flight passes either in between or through the plane of Mars and Earth's orbit can be referred to as “Asteroids of interest” (for Earth/Mars & Mars/Earth transfers). Additionally, by only looking at the asteroids for which pass through or travel along this desired plane we would in turn be reducing the overall number of possible “target asteroids” to a much more manageable size/list. Once finding an asteroid or list of asteroids of interest we can begin to evaluate the orbits of each individual asteroid for their dates and distances of their critical points (close approaches) for the purpose of generating a combined list of target asteroids. Our target asteroids can be defined as an orbiting body in space that possess a close approach at some point in its orbit that is close to the planets or the orbits of these planets we are trying to travel to. By compiling this list of target asteroids we not only slim our study (group focused on 6 Target asteroids listed below) down even further using our online database, we now have an understanding of the following information for which we can then use it to start planning our mission: the name of each target asteroid, the dates and estimated measurements of their close approaches along with the locations on their respective orbits pertaining to both Earth and Mars, their speed of travel and the estimated time of travel. The importance of taking this approach when beginning to use this idea/method for NEOs is because there are more and more recorded asteroids every year which means new target asteroids may present themselves at any time. There are NEOs that have not yet been discovered making it extremely difficult to know exactly what is going on in space without more advanced technology.

Continuing on with our mission to Mars, the next issue to be addressed is how we are going to use these asteroids to protect our crewmembers and shuttle from large amounts of radiation exposure while on these target NEOs. We proposed that through the use of specially designed robots, we can drill into the surfaces of these asteroids and burrow ourselves in a protective area based on the material composition of the NEO as well as its size. Volatile-rich NEOs may benefit this type of mission more because these volatile-rich NEOs can be used for solar or nuclear energy which can be extracted and used to make rocket fuel and reaction mass. Also in space the importance of water is immense because not only is it vital to sustaining life, but it can also serve as an effective shield against radiation. This indicates that from a mission planning perspective where timing is everything, the focus of our proposed idea for NEO transportation and radiation shielding will focus around finding asteroids that meet both these standards before being considered a target asteroid. Assuming that our target asteroid(s) meet our composition standards and are big enough to shelter our crew and their shuttle from harmful radiation, we can officially use them as a means of transportation to Mars and Back. if our NEO does not contain an ideal returning orbit we can alter the NEO’s orbit by attaching thrusters which will allow to stay longer, reduce the difficulty of the mission (selecting/finding another NEO) and return to Earth. From a realistic standpoint it may seem a little science fictional, however it is interesting to note that and idea such as this one is actually possible using almost all of the present technology already developed.

We must also determine the dates of all the expected launches we anticipate on needing in order to get from earth to our target asteroid as well as from the asteroid to Mars. We also need to know the two additional launches necessary for our return home either using the same target asteroid or another. It's important to keep in mind that as the number of launches increases so does the difficulty/complexity of the entire mission. For the sake of making our mission less complex with having four different launches to complete this trip, we would extract the volatiles on our transporting asteroid using nuclear energy technology on board our space shuttle and we could launch directly from Mars to the nearest usable NEO using our newly created fuel. The decision on whether we use the same target asteroid to return home directly relates to the amount of time we anticipate our mission to take (experiments, measurements that are prime motive of the entire mission) and also on the orbit of our target asteroid's close approach time. The two main purposes of the sending the robots to our target asteroid(s) would be for the following two reasons. To eliminate the risk of radiation exposure to humans while constructing (excavating) our radiation protection zones, and to make the process of landing and leaving this target asteroid as simple and as safe as possible. We also would have our robots attach thrusters(if necessary), which would allow us to control the asteroid in the event that more time is needed to complete the Mars mission while still being able to hitch a ride back to Earth. The final stage of executing this Earth/Mars transfer would be to figure out the timing of all the events. (Sending the robots, the 3-4 anticipated launches, etc.) We also need to calculate how long we would stay on our asteroids and when we would need to leave to get to mars along with leaving Mars to meet up with the asteroid to return to Earth.

Below are our group's 6 Target NEOs that we chose to base our study and the execution of our Earth/Mars and Mars/Earth transfer. This information includes tables stating all the possible close approaching times and distances up to the year 2100 along with a graphical display of our case study target asteroid (best NEO) 2008 EV68. Any additional known information about NEOs either not included below or relating to an NEO not listed below can be found on the link listed above. We believe these asteroids are very feasible NEOs to use for this transportation.

Target Asteroids for Earth/Mars & Mars/Earth Missions

1999 YR14

From 1950 to 2100							
Planet	Date	MJD	Nominal distance (au)	Min possible distance (au)	Stretching (au)	Width (au)	Close app probability
EARTH	1950/11/04.37820	33589.4	0.0805570	0.0805407	2.201e-5	5.045e-7	1.00e+0
EARTH	1967/11/17.25946	39811.3	0.1972500	0.1972140	2.661e-5	4.822e-7	1.00e+0
EARTH	1999/08/23.26651	51413.3	0.1241060	0.1240960	3.600e-6	4.881e-7	1.00e+0
EARTH	2016/09/01.48492	57632.5	0.0558267	0.0557930	1.313e-5	4.722e-7	1.00e+0
EARTH	2033/08/17.22862	63826.2	0.1872040	0.1872020	1.699e-5	4.517e-7	1.00e+0
EARTH	2069/11/05.40788	77055.4	0.0800359	0.0800094	4.410e-5	4.988e-7	1.00e+0
EARTH	2086/11/03.40390	83262.4	0.0676898	0.0676768	2.550e-5	5.054e-7	1.00e+0
MARS	2087/03/05.46906	83384.5	0.0384596	0.0384375	2.216e-5	5.337e-7	1.00e+0

Table 3. Close Approach dates and measurements of 1999 YR14

Credit: http://newton.dm.unipi.it/neodys/index.php?pc=1.1.8&n=1999YR14

Physical Attributes (known)

Orbital Type:AP

Diameter:0.5 – 1.1 Km

H:(Magnitude)18.90

G (gravity):0.15

2001 US16

From 1950 to 2100							
Planet	Date	MJD	Nominal distance (au)	Min possible distance (au)	Stretching (au)	Width (au)	Close app probability
EARTH	1955/06/20.90727	35278.9	0.0433685	0.0433674	7.552e-7	1.849e-8	1.00e+0
EARTH	1974/04/13.34434	42150.3	0.1525820	0.1525820	3.701e-7	5.501e-9	1.00e+0
EARTH	1985/07/02.69410	46248.7	0.0880068	0.0880059	9.618e-7	2.061e-8	1.00e+0
EARTH	2004/05/08.68153	53133.7	0.0284989	0.0284989	6.862e-9	5.724e-9	1.00e+0
EARTH	2034/05/03.96953	64086.0	0.0316526	0.0316499	9.521e-7	5.850e-9	1.00e+0
MARS	2039/06/26.53801	65965.5	0.0483808	0.0483736	2.845e-6	2.108e-8	1.00e+0
EARTH	2045/06/22.19304	68153.2	0.0423525	0.0423481	4.754e-6	1.951e-8	1.00e+0
EARTH	2075/05/18.70026	79075.7	0.0298396	0.0298242	5.792e-6	8.699e-9	1.00e+0
MARS	2088/05/19.27167	83825.3	0.0374600	0.0374155	8.640e-5	2.281e-8	1.00e+0

Table 4. Close Approach dates and measurements of 2001 US16

Credit: http://newton.dm.unipi.it/neodys/index.php?pc=1.1.8&n=89136

Physical Attributes (known)

Orbit Type:AM

Diameter:270 – 610 m

H: (Magnitude):20.290

G (gravity):0.30

Rotation Period (hrs.):14.39

Quality:2!

Light-curve Amplitude (mag):0.9

Radar Observations:Y

(! Quality code according to Lagerkvist et al. (1989) in “Asteroids II”(Eds. R.P.Binzel et al.), ‘ Univ.Ariz.Press,Tucson,USA, pp. 1162 – 1179.

2003 GA

From 1950 to 2100							
Planet	Date	MJD	Nominal distance (au)	Min possible distance (au)	Stretching (au)	Width (au)	Close app probability
EARTH	1958/05/07.84276	36330.8	0.1203710	0.1203410	1.071e-5	5.634e-8	1.00e+0
MARS	1971/12/04.86686	41289.9	0.0288226	0.0288075	5.964e-6	9.362e-8	1.00e+0
EARTH	1987/06/13.87989	46959.9	0.0717791	0.0717771	6.854e-7	4.450e-8	1.00e+0
EARTH	2003/05/15.28165	52774.3	0.0704934	0.0704933	6.908e-8	3.226e-8	1.00e+0
EARTH	2032/06/28.01633	63411.0	0.0790713	0.0790662	1.911e-6	7.185e-8	1.00e+0
EARTH	2048/05/14.04595	69210.0	0.0749071	0.0748913	5.550e-6	5.750e-8	1.00e+0
MARS	2054/09/07.97217	71518.0	0.0295513	0.0295384	4.641e-6	9.115e-8	1.00e+0
EARTH	2077/07/02.99981	79852.0	0.0826400	0.0826303	8.350e-6	7.604e-8	1.00e+0
EARTH	2093/05/18.86159	85650.9	0.0644402	0.0644127	1.243e-5	5.917e-8	1.00e+0

Table 5. Close Approach dates and measurements of 2003 GA

Credit: http://newton.dm.unipi.it/neodys/index.php?pc=1.1.8&n=2003GA

Physical Attributes (known)

Orbit Type:AM

Diameter: 180 – 400 m

H :(mag)21.10

G :(gravity) 0.15

Rotation Period :(hrs.) 5.78

Quality:3!

Light-curve Amplitude :(mag)1.25

2005 ER95

From 1950 to 2100							
Planet	Date	MJD	Nominal distance (au)	Min possible distance (au)	Stretching (au)	Width (au)	Close app probability
EARTH	1955/03/09.50551	35175.5	0.1142360	0.0322519	1.090e-1	3.009e-8	5.74e-1
EARTH	1978/03/14.52278	43581.5	0.0695734	0.0322139	3.341e-2	4.374e-8	1.00e+0
EARTH	2005/03/27.19353	53456.2	0.0332070	0.0331406	2.369e-5	2.954e-8	1.00e+0
MARS	2011/04/12.83687	55663.8	0.0461697	0.0417965	3.713e-3	8.143e-8	1.00e+0
EARTH	2028/03/21.45436	61851.5	0.0368411	0.0332318	2.584e-2	7.061e-8	1.00e+0
EARTH	2055/03/07.52585	71698.5	0.1653160	0.0327189	3.742e-1	2.581e-8	1.74e-1
EARTH	2055/06/04.01514	71787.0	0.1906800	0.0327183	2.644e-1	2.296e-7	1.69e-1
EARTH	2059/04/19.08655	73202.1	0.1077090	0.0331188	3.233e-1	6.989e-8	2.06e-1
MARS	2064/01/02.15042	74921.1	0.0140901	0.0035187	6.506e-2	1.086e-7	2.54e-1
EARTH	2082/03/07.75604	81560.8	0.1691720	0.0336699	9.062e-1	2.788e-8	4.80e-2
EARTH	2082/06/05.26223	81650.3	0.1926390	0.0336695	6.281e-1	1.831e-7	7.89e-2
EARTH	2086/04/22.90587	83067.9	0.1397770	0.0342327	9.453e-1	9.064e-8	6.98e-2

Table 6. Close Approach dates and measurements of 2005 ER95

Credit: http://newton.dm.unipi.it/neodys/index.php?pc=1.1.8&n=2005ER95

Physical Attributes (known)

Orbit Type:AM

Diameter:20 – 50 m

H:(mag) 25.40

G:(gravity) 0.15

2007 EE26

From 1950 to 2100							
Planet	Date	MJD	Nominal distance (au)	Min possible distance (au)	Stretching (au)	Width (au)	Close app probability
EARTH	1953/03/03.85871	34439.9	0.1618810	0.0062173	1.031e-1	1.564e-6	4.10e-1
EARTH	1959/11/15.93298	36887.9	0.0723087	0.0173654	3.383e-1	1.869e-6	1.85e-1
EARTH	1977/11/15.03961	43462.0	0.0774696	0.0173535	1.450e-1	1.839e-6	4.35e-1
EARTH	1989/03/01.58801	47586.6	0.1204960	0.0058150	2.039e-1	1.322e-6	2.61e-1
EARTH	2007/02/18.79816	54149.8	0.0207888	0.0207211	8.167e-5	8.071e-7	1.00e+0
MARS	2008/12/08.12562	54808.1	0.0168859	0.0054613	1.451e-2	2.056e-5	9.32e-1
EARTH	2013/11/23.20415	56619.2	0.0328017	0.0177848	7.093e-2	1.736e-6	9.29e-1
EARTH	2032/02/23.50430	63285.5	0.0430781	0.0050960	3.609e-1	5.000e-6	1.83e-1
EARTH	2038/11/23.63135	65750.6	0.0358468	0.0177414	7.067e-1	2.197e-6	9.30e-2
EARTH	2057/02/10.32797	72404.3	0.0130101	0.0043229	1.834e+0	1.303e-5	3.63e-2
EARTH	2068/03/01.87206	76441.9	0.1117830	0.0043279	6.212e+1	2.102e-5	1.03e-3
EARTH	2085/11/09.71400	82903.7	0.1598660	0.0188820	7.095e+1	2.336e-6	7.28e-4
EARTH	2096/11/30.43141	86942.4	0.0193773	0.0188653	3.351e+1	7.570e-6	1.99e-3

Table 7. Close Approach dates and measurements of 2007 EE26

Credit: http://newton.dm.unipi.it/neodys/index.php?pc=1.1.8&n=2007EE26

Physical Attributes

Orbit Type:AP

Diameter:10 – 40 m

H :(mag)26.10

G :(gravity)0.15

Classifications of NEOs based on Physical Compositions

Many NEOs are classified as Chondrites, which can be composed of silicates (mainly of iron) and volatiles (mainly of iron, water and carbon). Iron constitutes for 88% of the main metal classifications of NEOs and other asteroids. Iron is the second best metallic element used to protect against gamma radiation being only second to lead. It only takes 4 inches of Iron to reduce gamma radiation damage by a factor of 10, whereas it takes 24 inches of water to reduce by damage by a factor of 10. Drilling down 340 feet of iron would reduce radiation damage by a factor of 1 million. We also need to take into account other properties on NEOs when determining their feasibility such as their temperatures.

The temperature on the NEO 433 Eros ranges from -150$_{o}$ Celsius to -100$_{o}$ during the day and has a temperature of 0 degrees Celsius on average. I believe the observed temperature is that high because of the NEO's close orbit to the sun. It is also important that humans utilize smaller NEOs as feasible options for transportation to and from planets. This is because the smaller NEOs can be attached to thrusters that humans can use to control the trajectory of the NEOs more easily. This will make space travel easier because once a smaller NEO is traveled to a desired planet, I believe that the thrusters can be manipulated so that the NEO stays in orbit of the planet until humans wish to depart from that planet and ride it elsewhere. This would make space travel much easier for humans, while using the NEO for radiation protection against deadly cosmic radiation. We would want to use several small thrusters and attach them to the small NEO that we want to use (see Figure 22). The thrusters that we would attach to the NEO would allow us to alter the trajectory by changing its velocity (see Figure 23).

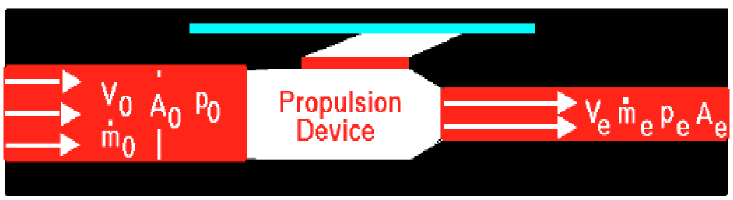

Fig. 22. An example of a thrust

Credit: http://www.grc.nasa.gov/WWW/k-12/airplane/thrsteq.html

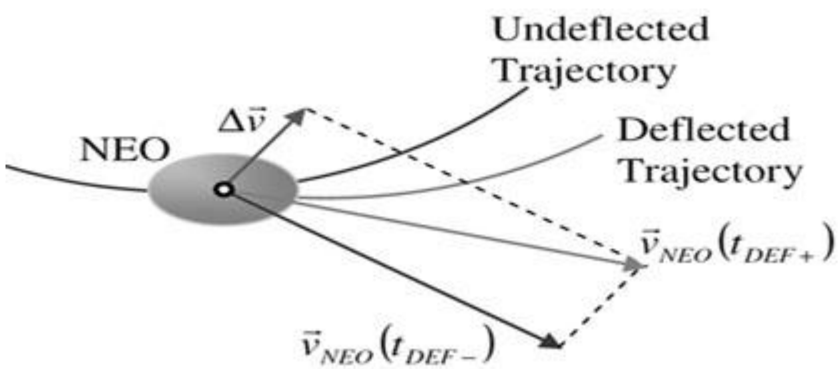

Fig. 23. Manipulating an NEO's velocity using thrusters can change its trajectory

Credit: http://www.airpower.au.af.mil/apjinternational/apj-s/2009/1tri09/barbeeeng.htm

Case Study: 2008 EV68

One of the more promising NEOs we considered is 2008 EV68. First observed March 3rd, 2008, this Amor will have several close encounters with Earth and Mars in a timespan that makes possible its use as a vehicle for interplanetary travel.

We used the following table of 2008 EV68's close encounters to propose a possible timeframe for a mission to Mars:

From 1950 to 2100							
Planet	**Date**	**MJD**	**Nominal distance (au)**	**Min possible distance (au)**	**Stretching (au)**	**Width (au)**	**Close app probability**
EARTH	1978/02/08.88611	43547.9	0.1333630	0.0808150	1.244e-1	5.656e-6	5.33e-1
EARTH	2008/01/28.94991	54493.9	0.0810180	0.0810180	1.023e-4	5.508e-6	1.00e+0
MARS	2009/06/29.90201	55011.9	0.0326205	0.0106150	7.182e-3	1.565e-5	1.00e+0
MARS	2037/09/16.90228	65317.9	0.0172110	0.0101185	1.121e-1	1.383e-5	1.45e-1
EARTH	2038/01/11.37894	65434.4	0.1187500	0.0807089	1.086e-1	1.696e-6	6.05e-1
MARS	2065/12/03.28379	75622.3	0.0114152	0.0093689	8.425e-3	1.903e-5	1.00e+0
EARTH	2075/02/02.26385	78970.3	0.0859442	0.0803681	4.450e-2	5.979e-6	9.50e-1
MARS	2094/02/18.60978	85926.6	0.0351703	0.0081456	2.644e-1	1.378e-5	6.24e-2

Table 8. Close approaches of NEO 2008 EV68 with Earth and Mars
Credit: http://newton.dm.unipi.it/neodys/index.php?pc=1.1.8&n=2008EV68

We need to find two sets of dates relatively close together so that the astronauts could leave Earth for the NEO, hitch a ride to Mars and a small time period later, fly from Mars to the NEO that takes them back to Earth. Unfortunately, contrary to what we initially thought, 2008 EV68 does not look like it could be used as a method of getting to Mars. One would need to find a different asteroid that allows astronauts to conduct a mission on Mars in the time period before it is used during the return trip.

While a handful of NEOs can take astronauts from Earth to Mars, 2008 EV68 is one of the only NEOs we found that serves as a ride back. The dates we are considering for the return trip are 9/16/2037 - 1/11/2038, a quick 4 month journey. Those dates aren't taking into consideration the time it takes to travel between the NEO and the respective planet, however, so the actual return trip would start sooner and end later. The astronauts will need to be on the planet for 6-18 months before they leave for the NEO, so further research will have to be done to find an appropriate asteroid that will pass by Earth and then Mars sometime around autumn of 2036.

Using the Orbit Diagram Simulator from California Institute of Technology's Jet Propulsion Laboratory, we can provide a rough diagram of the orbits of the NEO, Mars, and Earth at each of the given dates for the return home.

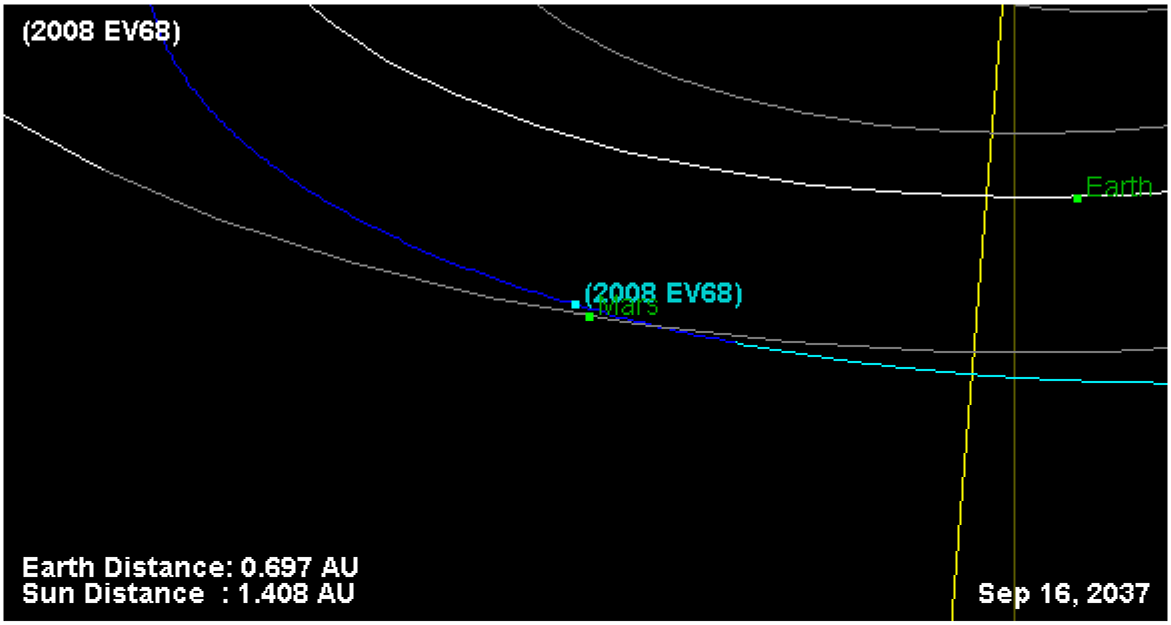

Fig. 24. Orbits of the NEO and Mars at the beginning of the proposed return trip. The lighter blue line of 2008 EV68 is when it is above Mars, the darker blue line is when it is below Mars. This picture is viewing the two celestial bodies from below.

Credit: http://ssd.jpl.nasa.gov/sbdb.cgi?orb=1;sstr=2008+EV68

2008 EV68 is .017 au away from Mars at this point in time. The astronauts would leave Mars a few days before 9/16/37 to travel the shortest distance.

$$.02\text{au} * \frac{92{,}955{,}807.3 \text{ miles}}{1 \text{ au}} * \frac{1}{594960 \text{ mpd}} = 3.12 \text{ days}$$

Fig. 25. Calculate the time it takes to travel .02au going ~600k mpd.

Less than four months later, 2008 EV68 approaches Earth within .12 au:

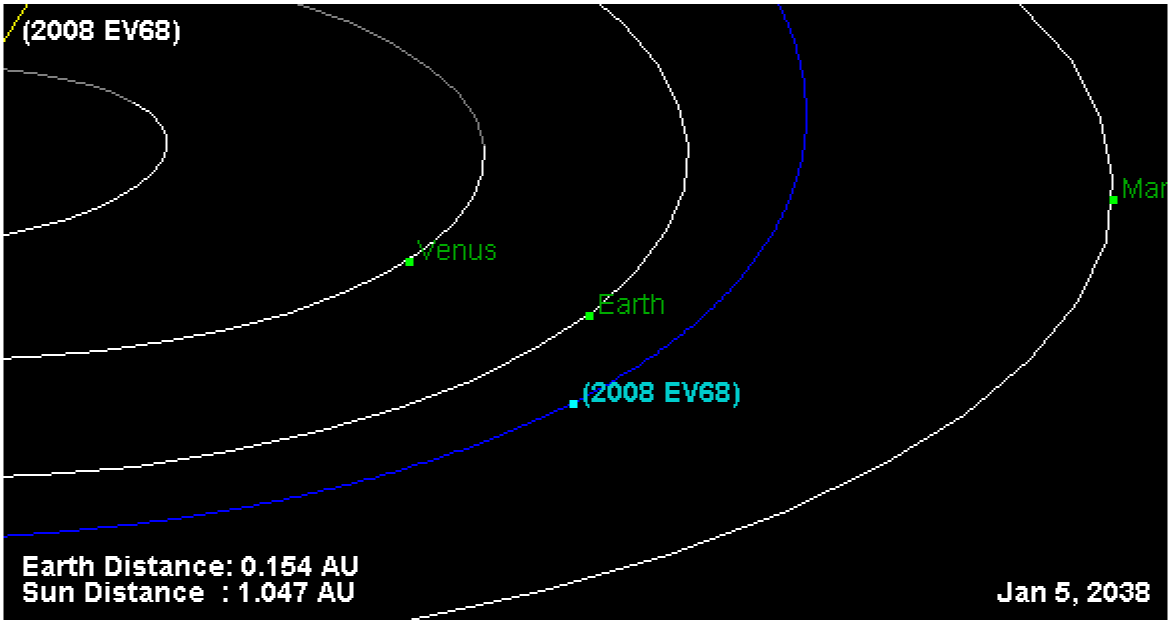

Fig. 26. Orbits of the NEO and Earth at the end of the proposed return trip.
Credit: http://ssd.jpl.nasa.gov/sbdb.cgi?orb=1;sstr=2008+EV68

Note that Figure 26 is an approximation. This explains the discrepancy in distance between Earth and 2008 EV68 in the figure and in Table 8.

Crossing the .12au gap will take the astronauts 19 days (see figure 27), making the total time spent traveling without the protection of an NEO 22 days. Because this is such a small period of time, I believe that given current technologies, if we are able to successfully utilize NEOs as a mode of transport, humans will walk on Mars by the year 2038.

$$.12\text{au} * \frac{92{,}955{,}807.3 \text{ miles}}{1 \text{ au}} * \frac{1}{594960 \text{ mpd}} = 18.74 \text{ days}$$

Fig. 27. Calculate the time it takes to travel .12au going ~600k mpd.

Resources to Utilize in Future Research

We have looked into several possible NEOs to use as a vehicle for interplanetary travel. To do so, we have taken advantage of the extensive information provided to the public by the two year old Near-Earth Object Human Space Flight Accessible Targets Study (NHATS). The database we used is described as a "tool to identify future observing opportunities for those near-Earth objects that may be well-suited to future human space flight round trip rendezvous missions". The NHATS database gives sundry information on each NEO cataloged, including its projected orbit for the next century.

Another immensely useful resource that we frequently visited is NEODyS, a tool sponsored by the European Space Agency that "provides information and services for all Near Earth Asteroids". This website serves as another source of information regarding any known NEA. In our experience, it is best to use both resources when investigating an NEA, as they each provide their own information.

Chapter 4: Reference to Collaborated NEO Paper

Based on our research and collaboration with another IQP group, we have written a paper to be submitted for publication in a scientific journal (see attached document). This paper has duplicated content because it was written using our findings from this IQP, but it also has unique and original content that is a result from our collaboration with the other IQP group.

Chapter 5: Societal Aspects

Societal Overview of Humanity in Space

One of the most important goals that we can take into account for an overview of space colonization is the survival of the human race. Colonies on new planets to colonize must be supplied with abundant resources that will suffice human life and growth. The first pioneers to colonize a new planet will need to survive and reproduce in order for a colony to be successfully established. Radiation protection, water and food supply, and oxygen supply will all need to be put at top priority for new colonies. NEAs need to be utilized to protect humans against radiation en route to new planets as well on the planets that humans will be colonizing.

Humans will most likely have adapt to a new way of life as they will ideally find themselves living beneath the surface to protect themselves from radiation along with other harmful forms of space weather. Additionally, humans will be faced with dangerously low levels of breathable oxygen if any exist at all upon their arrival into this new world. One idea that may serve as a stepping stone to this problem will be the construction of large areas of vegetation combined with a vast network of air ventilation systems to help disseminate these breathable gases amongst the rest of the underground community in Mars. This process would require both a large amount of oxygen-producing vegetation such as algae, and a substantial amount of time for the vegetation to successfully make the underground colony habitable. The use of algae would be an ideal solution to this problem associated with producing breathable gases because in the early stages of the colonization process the use of highly efficient materials is going to be the most crucial aspect. In achieving this demand for highly efficient materials, Algae offers many advantages to the early development of a space colony as it provides the following uses such as a stable food source due to its protein and amino acid rich qualities as well as containing carbohydrates believed to boost the response of the immune system, A fuel source because of its ability to make biodiesel and bioethanol as well as substantial amounts of vegetable oil, the production of gas molecules like oxygen and hydrogen, and finally its ability to create biomasses that can be burned to provide a source of heat and electricity. Continuing further, humans will be forced to make changes to everyday jobs such as the designing and construction of buildings due to the drastic change in Mars' gravitational pull. Upon being the dominant species for hundreds of years, humans have found ways to improve/create technology and living standards to adapt to the new challenges that life on Earth has presented. However, adapting to life on another planet provides a whole new level of challenges. The different environment on Mars will require us to take a new approach in how we will conduct everyday processes. This includes basic things such as mixing cement to the ways in which we harvest and produce food. Most likely, the bases to house human societies will need to be underground to protect people against radiation. In the new colonies, humans will have to work out more physically to build and retain sufficient muscle growth. Humans on the colonies will need to be more self-sufficient with being able to handle day-to-day activities that involve spaceports as well as energy production and food production. Humans will have to learn how to use and develop new materials on the planet; the first group of humans that will colonize and populate the planet will have to be highly educated in science and math so that more engineers and scientists can be produced to aid in the rapid development of the planet colony.

One important question that should be addressed is should the same laws from the United States apply? I believe that it is critical that humans will have to redefine possession of colonies once space colonization becomes more prevalent. Governments will have to be established and new laws will be made on the planets that will be colonized for new US territories. The more advanced countries that will be big players in space colonization will have to meet with the UN or separately to decide on how to split territory possession on planets. These actions are absolutely necessary so that war and tension can be prevented over colonization of planets between different countries.

Societal Aspects of the Sun's radiation on Earth

When evaluating the effects of the sun on Earth, one should consider how important the sun is. The sun is responsible for heating the earth's surface, its oceans as well as heating its atmosphere. The sun is also responsible for providing a large amount of energy to our atmosphere, which is the primary cause today's weather patterns. The climate change experienced on earth is a direct result of the amount of radiation the earth is exposed to. As the earth changes in its albedo- that is also known as the amount radiation reflected back from the earth's clouds and surface. The radiation emitted from the sun changes with the solar activity such as solar flares or sunspots.

Due to recent climate and weather changes scientists have begun trying to link these changes with short/long term solar cycles. Additionally, scientists have also looked into the possibility of a relation between earth's climate changes and solar variability. Their Focus was shifted on the influence of solar radiation that the sun emits and a possible correlation to changes in sunspot cycles, but was concluded to be minimal if in fact any relation did exist.

This leaves the question of how the sun can affect earth. This answer is not quite black and white, whereas there could be many plausible explanations for what the sun will eventually do to the earth. Perhaps one of the most problematic events to occur in the future would be the deterioration of Earth's magnetic field. Research shown, through the study of unusual seismic tremors taking place under the Mid-Atlantic Ridge that the earth's magnetic field is in a state of rapid decline. Also as the earth's core continues to move, as a result of the Poles moving by about 40 miles a years, the north and south magnetic poles will begin to switch places for the first time in 780,000 years. It has been speculated that during the era of the Roman Empire, the Earth's magnetic field was estimated to be nearly 2x as strong as today. This brings scientists to believing that if there were once times consisting of very high heat-flux coming from the mantle as well as an increase in hotspot activity, then it is very likely that the earth will again become susceptible to similar events during this magnetic reversal.

Another way the sun's radiation will affect earth in the future will be from a change in space weather. "Space weather" refers to naturally occurring events in space such as a Coronal Mass Ejection, being the strongest and most deadly solar flare. When a CME occurs, a massive amount of high-energy protons are shot out at speeds expected to be about four million-miles-per-hour and are typically associated with solar wind. One important thing to understand is that even if we are not directly hit with a CME or another type of space weather, the effects are still devastating and most likely lethal. Some of the things that would result from the earth being hit by a CME would be the disruption of Earth-based power grids meaning that all forms of electricity would be terminated. Additionally, there would be a disruption of all satellite operating global positioning systems, which poses a major risk for astronauts beyond low-earth- orbits. These few results are extremely crippling for humanity because with the loss of electricity comes: the inability to use almost every form of technology that exists today, planes falling from the sky, hospitals being shut down and the elimination of any form of communication. These effects caused from a loss of electricity can be comparable to taking mankind from the 21st century back to the dark ages.

Bioengineering

Bioengineering is a growing field that will have a large impact on the way humanity defines what life is and as well how humans will tackle the radiation issue. The way humanity defines life is a heated debate based on many different biological factors. One of the ways biologists try to define life is through understanding the entire genome sequence of a living organism and how the expression levels of different genes are regulated. Complete genomic sequence analysis gives humans the ability to study the background of an organism's genetic makeup. In other words, genome sequencing gives humans a clue as to what the karyotype of organisms are or the complete set of chromosomes in living organisms. Once the entire nucleotide sequence is discovered, researchers can create phylogenetic trees to further analyze an organism's genetic background. Phylogenetic trees are tools used by biologists that provide the lineage of the evolutionary pathways from ancestral organisms to their current descendants. If humanity has the passion and curiosity to discover what life really means and how we can protect humans from radiation, then we as a society will need to develop visionary ideas on how to discover the human genome.

One idea of mine is to manipulate a gene to secrete proteins that would supply the skin with hydrogenous materials to code the cells to protect against radiation. These materials could absorb the neutrons in radiation particles and protect humans from the secondary radiation particles from GCRs. The insertion or deletion of genes is part of the field of Gene Therapy. Gene therapy is an interesting but promising field that could possibly cure human diseases caused by radiation at the genetic level. It also could be used to force human genes to begin production of abnormal proteins that would contain hydrogenous materials. One way to accomplish this is to utilize alternative splicing in human genes. Alternative splicing is a process by which RNAs in humans are cut, or "spliced," of parts of their genetic material to create different mature RNAs (mRNAs). The regions that are spliced from RNA molecules in this process are non-protein-encoding regions called introns, and the regions that are left are protein-coding regions called exons. Alternative splicing works through splicing different parts of exons in the RNA molecule and can ultimately create a new protein from the norm. We could analyze the nucleotide sequence that makes up a human gene and figure out what sequences to splice to create an mRNA that could code for a hydrogenous protein. This mRNA molecule would then be translated using tRNA to create the amino acid sequence of this useful protein from the information in the mRNA molecule. A tRNA molecule is a functional RNA molecule that does not code for proteins. It instead helps carry a three-nucleotide sequence called an anticodon to code for the amino acids to form a protein. This process of translation is what ultimately creates the protein that we want.

In accomplishing the manipulation of a gene to secrete proteins that would supply the human skin with hydrogenous materials, we could perform a point genetic mutation in the human DNA nucleotide sequence. This would require research into what proteins or enzymes can produce hydrogen or polyethylene. If we can learn the amino acid sequence for an enzyme that can do just that, then we could create a point mutation in the DNA nucleotide sequence to code for that particular enzyme. This same idea could apply to a natural phenomenon by human cells in Biophysics. Many cells can generate electromagnetic fields through emitting pulses. Using this creative idea of gene manipulation, we can try to manipulate cells to generate greater pulses of these fields, which could then create more electromagnetic fields to deflect against radiation. While both these processes could produce gratifying results, we must think ahead into what the future of bioengineering could lead to. Personalized Medicine is becoming a growing subfield within Bioengineering: many farmers are using it to try to produce the most desirable crops or flowers such as longer stalks and desired colors for flowers. If we can produce proteins or enzymes that could develop hydrogenous “shields” for humans, then there is the possibility that we could create a desired child or even soldiers that could survive deadly radiation in space. These could be feasible treatments/methods in the next 50 years if more research is initiated. Bioengineering could become a very big ethical debate in human scientific research.

Chapter 6: Advice for Future IQP Research

Several areas of our research can be expanded upon in future IQP projects that deal with the societal aspects of humanity and space. One such area is the use of meteorites as a means of transportation and radiation protection. Our group focused on the use of Near Earth Objects for these purposes, but meteorites could pose as another viable solution. Our group would have also liked to include in our paper the use of robotics and artificial intelligence. The use of robotics is necessary for the domestication of NEOs for human habitation and transportation. A thorough plan for the construction and implementation of these robots would help future work for NASA and other organizations that seek to use robotics to make space colonization an easier feat to accomplish. It is also necessary for future work to decide how human colonies will be constructed on other planets. Human society will indubitably become affected by living on an alien planet, and we will need to decide how living quarters will become arranged underground in new planets.

Chapter 7: Conclusion

Humans have dreamed of going into space since the realization of its existence. Only very recently, however, have we achieved this goal, and there exists abundant ambition to pursue it even further. Among the many obstacles preventing us from delving into space, radiation remains one of the biggest threats to humans. If an astronaut was exposed to space radiation without any protection, there would be no chance for survival. For example, coronal mass ejections and galactic cosmic rays would be instantaneously lethal to any human on contact. Even when exposed to nonlethal space radiation, many fatal diseases can develop if they are not treated.

To combat against space radiation, we need to either prevent exposure or be able to withstand it effectively. One method to prevent exposure is through the use of Near Earth Objects. Their use will both shield humans from radiation and provide convenient transportation across the solar system. However, it should be noted that NEOs can be just as destructive as they are beneficial if, for example, one collides with Earth. A supplementary method to prevent exposure is the use of radiation-blocking materials such as the polyethylene derivative, Demron. One method to withstand the exposure of radiation is through the usage of bioengineering. By the manipulation of particular human genes, it may be possible to create a radiation-hardened human.

The exploration and colonization of space will have a tremendous impact on human society. The survival of the human race is, of course, the most important side-effect of expanding into space. Being able to adapt to the conditions that outer space and other planets provide is essential to the success of space colonization. Examples of this include an increased need to exercise so that muscles will not atrophy in a low gravity environment. The political aspect of colonizing space will be similar to those in the colonization of the New World. The space race will surely impact the struggle and survival of the many nations of Earth. In the same way that land creatures adapted to their new environment after evolving from aquatic creatures, humans will need to adapt to our new, cosmic environment.

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