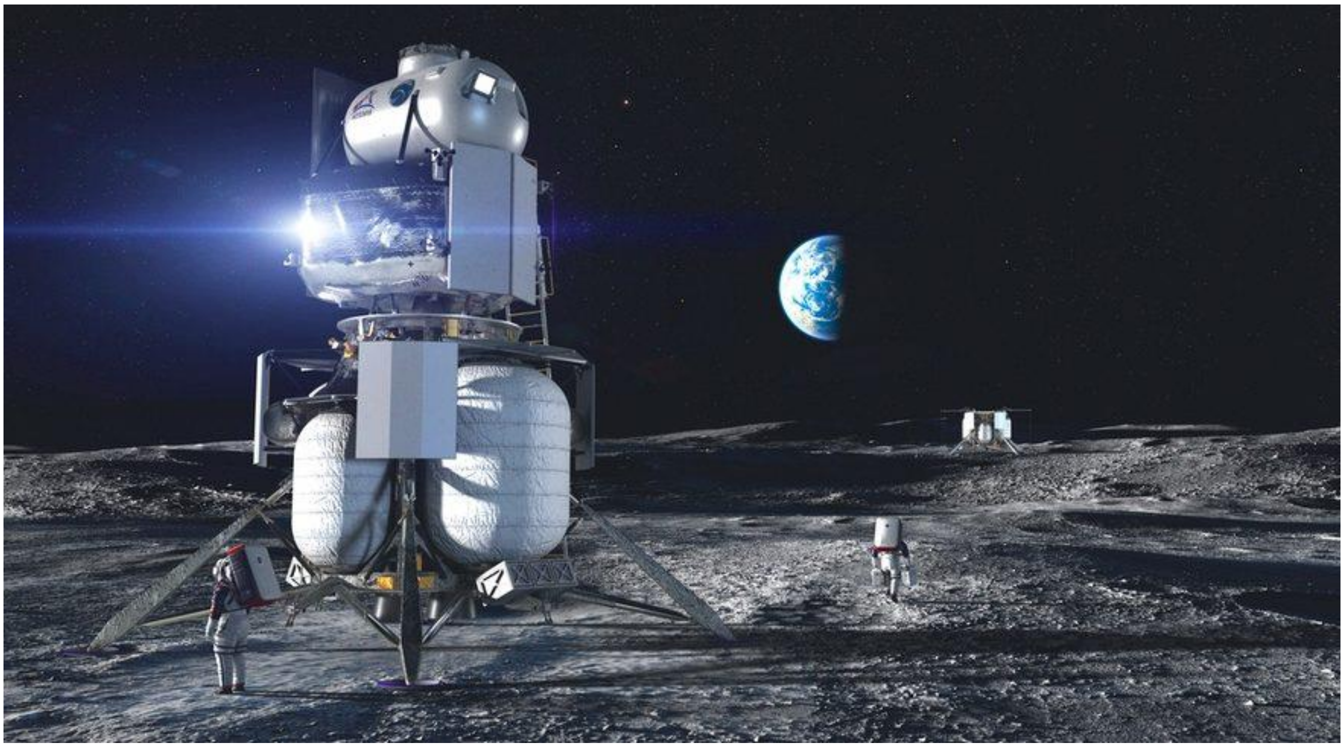
Humanity And Space: Path to Lunar Permanence and its Advantages



by

Michael Scalise

Humanity and Space: Path to Lunar Permanence and its Advatages

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by
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ABSTRACT

Humanity is preparing to expand its reach into deep space shortly, beginning by revisiting the Moon. This project explores the concept of colonizing Earth's closest neighbor, the Moon, to help serve humanity's needs. To accomplish this, this paper presents an overview of the U.S. Space Policy and information on topics such as current NASA programs, lunar volatiles such as helium-3, and fusion reactors. This paper analyses topics such as: a viable location for a lunar base, the advantages of the Moon for humanity, electromagnetic acceleration in space, the use of robotics, and the sociopolitical effects of a lunar colony. This overview seeks to aid in selecting research topics for future papers, allowing for a more in-depth analysis of the concepts presented.

ACKNOWLEDGEMENTS

I would like to express my great appreciation for the valuable help and guidance I received from Professor Mayer Humi, my research advisor. Thank you for your time and commitment to this project. The level of success of this project would not have been possible without you.

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EXECUTIVE SUMMARY

Presently, there are a wide variety of factors that may lead to the mass extinction of humans. For example, humanity's current use of fossil fuels is causing a noticeable impact on the Earth's ecosystem. Climate change is causing Earth's snow caps to melt, oceans to rise, as well as a countless number of other negative impacts. Other risk factors to the sustainability of humanity include colliding asteroids, human-created apocalypse-like nuclear war strategies, and mass viruses. These changes can have drastic effects on human existence as they may lead to Earth becoming an uninhabitable planet. This leaves humanity to search for a way to sustain its existence in the long run.

The solution to these problems cannot be found on Earth. The solution to humanity's survivability is to expand humanity into space. Currently, the Moon is the closest and simplest option to help sustain human existence. The United States issued their policy on space, and in short, it set goals and guidelines to maintain a sustainable use of space for all nations. At the same time, it declared the United States would work to maintain its leadership in this field. To stay on track, NASA is currently working on a program to maintain its leadership in space by extending human space travel farther than has ever been traveled before. The program, titled Artemis, will utilize state-of-the-art gear to launch into orbit and plans to revisit the Moon to begin long-term exploration and utilization of its surface. The policy states that it will work to discover and utilize space resources to aid in increasing the quality of human life. The Moon contains a renewable supply of helium-3, a rare element that is a key ingredient in creating clean energy through nuclear fusion. Unlike fission, the energy released is far greater and does not create any harmful radioactive by-products. This technology is still being researched and is not yet perfected. However, fusion technology is increasing every day on Earth, and multiple nations agree that helium-3 is essential. Many nations are looking toward the Moon to gain access to helium-3, potentially leading to another space race. If properly used in a fusion reactor, the supply on the Moon can power the Earth for around 10,000 years.

While mining on the moon is an important step in helping humanity prevail, colonization and full utilization of the attributes of the Moon will further aid in humanity's survivability. As a single-planet species, humanity is vulnerable to any global catastrophe. In a worst-case scenario,

this will allow a portion of the species to continue to expand, consistent with U.S. policy to "enhance operational efficiency, increase capacity, and reduce launch costs by investing in the modernization of space launch infrastructure." The use of the Moon's environment will also act as a catalyst for expansion and security, as the Moon's lack of atmosphere is perfect for launching shuttles, rockets, and asteroid interceptors more efficiently, allowing for farther reach with present technology.

However, colonizing the Moon does not come without risks. One of these potential risks is the exposure to harmful particles, radiation, and galactic cosmic rays. On Earth and in the International Space Station, we are protected by Earth's Van Allen Radiation Belts, which block most incoming particles. These Belts are not present on the Moon. Another risk will be the decrease in gravity, which will cause muscle and bone atrophy. These factors will cause long-term damage to astronauts and colonists without proper care. If these conditions were harsh enough, the Moon's lack of atmosphere allows for micro-meteor impacts that can devastate the colony structure if not properly armored. If continuous Moon exploration and colonization is to be tested, it is crucial for safer techniques to protect against these risks.

Fortunately, humans do not need to take these risks alone. They will have robotic counterparts that will be utilized in almost every situation possible. There will be no need for manual labor in mining the Moon. Humanity will be fully taking advantage of its current technology and have robots mining and transporting the helium-3. Other tasks performed by robots and computers include reconnaissance of new areas to explore, construction of equipment and infrastructure, routine jobs such as agriculture, and overwatch of all the different components, allowing for faster reaction and security. As the infrastructure on the Moon is increased, and the outpost turns into a colony or even a society, robots will be everywhere, from companions to cooks.

As the initial outpost of essential workers increases to the everyday person, there will be a sociopolitical and economic effect on that area. There will be a drastic change in the need for skills as the personal diversity of the colony shifts. Since no nation is allowed to claim ownership of anything outside of Earth, the Moon will need its own infrastructure. What type of government will be formed? How will they maintain law and order? How will currency work due to the colony being started by multiple nations? How will human species evolve due to the Moon's environment? These questions are difficult to speculate on, but the answer will set a precedent for future colonization.

The idea of space travel, living on a different celestial body, and discovering the unknown has always been a science fiction fantasy. Space is truly humanity's final frontier. The idea of being able to colonize various planets and travel between them is a fascinating feat. Since the iconic Apollo missions that resulted in a total of 12 astronauts stepping foot on the Moon, no human has gone back or beyond. The Artemis program is set to change that a lot sooner than anticipated. Not only is the Moon the first step to testing humanity's expansion and ability to colonize a celestial body, but it also holds the key to preserving and sustaining humankind. The exact details of our expansion have endless results. Will we get to a point where our present day looks like it was taken out of science fiction such as Star Wars and Startrek? Will a lunar permanence consist only of robots? The answers are unclear, but the Artemis program is one small step in the right direction to solving what humanity's future looks like. Though there is still much work to be done towards this front, this endeavor will be the salvation of humanity.

Final Recommendations

This report focuses on bringing forth a broad range of current space travel topics. My goal was to benefit this field as I tried to cover various important topics to act as a review for future researchers. This includes everything from mining of helium-3, fusion reactors, current missions, advantages of the Moon's environment, and more. This leaves a broad start for future research to take one of these topics and dive deeper, providing a more in-depth report.

Each one of these topics has enough content to expand deep into, such as the cost and feasibility of being able to mine enough helium-3 to impact our energy crisis, and to expand more in-depth on the social, political, and economic outcomes of a society in space. From a biological perspective, the human species will be molded by other celestial planets. A future report can go deeper into the current technology that exists and in progress to be utilized in space. Finally, what is next? It is speculated after the Moon; Artemis' goal is Mars. If that is the case, how will the concept of lunar permanence be adapted to martian permanence?

CHAPTER 1: INTRODUCTION

Humanity is on a path to exhaust our home planet's resources. Pollution from fossil fuels and other non-renewable energy sources is destroying the environment. Earth's temperatures have risen per decade by 0.14 degrees Fahrenheit before 1880, and the current rate is more than twice that, with a 0.32 degrees Fahrenheit rise per decade since 1981. (Lindsey & Dahlman, 2022) This is causing detrimental effects, not only on animal species' ecosystems but humanity's as well. If we continue this path for much longer, humanity may be extinguished.

Not only is climate change a risk to humanity, but there are also other risk factors that may cause mass extinction. In recent years, humankind has seen firsthand how fragile their species is. The coronavirus pandemic started in April 2020 and, as of June 2022, has claimed over 6,341,240 lives. (Woldometer, 2022) Such events, as well as colliding of asteroids, and even nuclear war, have the potential to wipe out the human species. This combination of detrimental factors leaves humans to find better ways to sustain mankind in the long term which may include both a cleaner energy source and the preservation of the seed of humanity.

The answer to our energy crisis and humanity's survivability can be found in an unlikely location, the Moon. NASA has already confirmed its plans to revisit the Moon during its Artemis program and plans to utilize the Moon for new resources. A promising new form of energy is currently being tested, nuclear fusion. Different than nuclear fission reactors seen in Fukushima and Chernobyl, a fusion reaction does not produce any harmful radioactive biproducts. The key to creating a cleaner use of fusion reactions is the use of an extremely rare element found on Earth, helium-3. Unlike Earth, whose electromagnetic barrier blocks radiation and other particles like helium-3 from the Sun, the moon has been collecting these since the dawn of time. The ability to collect this helium-3 and utilize it in a fusion reactor will be the change in energy sources humanity needs to help sustain its growth.

Not only will mining on the Moon help humanity prevail, but so will colonization and full utilization of its attributes. As a single-planet species, humanity is vulnerable to any global catastrophe. In a worst-case scenario, this will allow a portion of the species to continue to expand. The use of the Moon's environment will also act as a catalyst for expansion and security, as the Moon's lack of atmosphere is perfect for launching shuttles, rockets, and asteroid interceptors more efficiently, allowing for farther reach with present technology.

It is important for this information to be easily accessible to the public to help spread awareness of humanity's next step. This type of awareness will also provide the attention needed to help attract more funding and research into the necessary technologies needed to help benefit all humankind. This report intends to provide an update to the field by taking into account the current technologies, NASA programs, and other space exploration projects.

This IQP seeks to contribute to the current research on space exploration by discussing the benefits of colonizing the Moon and providing an analysis of the current research in this field, and outcomes of this expansion. This research is salient with present society due to the status of the Earth's climate and the availability of clean renewable resources and the current intentions of NASA. While this research is currently underway, this project seeks to create a comprehensive resource to allow the general population access to information about current space exploration goals and projects. It is hoped that future researchers will utilize this project to gain an overview of the concepts discussed in order to guide a more in-depth understanding of the material presented.

CHAPTER 2: BACKGROUND

The United States Space Policy

Ever since America's first step on the Moon, the United States has been utilizing its space capabilities in various aspects of life. With the rise of current technology and ambitions, it is apparent that space will become more accessible. Life on Earth will be greatly enhanced due to the partnerships with various allies and the advancement of technologies needed to achieve America's goals set out in this policy. The United States recognizes that the upcoming space sector will be fundamental for new development in technology and an increase in the economy, creating new market opportunities.

Before going and exploring untamed, the United States wanted to clarify its principles, goals, and guidelines for proper space exploration and how various situations should be handled if it comes to it. Within this document the Untied States was very thorough in its intentions, and the guidelines for each role it foresees to be included in the Space sector.

Policy

The principles start with ensuring all nations should act responsibly in space to ensure safety and stability in a long-term space program. All nations and companies should operate with openness and transparency to ensure all humanity benefits.

Beyond the safety concerns, the United States wants to ensure that the commercial space sector stays competitive and that the United States will be a strong leader in this sector. Highlighting it will help nations that follow the same values as the United States in its pursuit of the Moon, and then Mars.

Even though the United States is asserting its dominance, it acknowledges that space is not controlled by a single nation or nations. Every nation should have access to it, and any nation that tries to deter this freedom, the United States will act accordingly to deter, counter, and defeat them if necessary.

Goals

The United States explains its various goals and what it will do when it comes to the space sector. As stated, the United States understands the market opportunity in the economy with the new frontier. The United States will promote private industry and help extend human economic activities in the space sector.

The United States will also promote and hold accountable the responsible and peaceful use of space by other nations, along with creating a safe and stable environment for long-term use. This will ensure that the space sector will help increase the quality of life for all humanity, not just the United States.

Although the United States wants all nations to be able to access space, its goal is to preserve the leadership of the United States in space, focusing on maintaining partnerships with allies and deterring nations who threaten these interests.

Guidelines

Foundational Activities

With the principles and goals clarified, the United States expresses what the guidelines are for each department and agency to assure success in their respective missions.

To ensure the fundamental activities are met while maintaining and strengthening the United States' leadership in the space sector. It will promote technological developments, STEM fields, and commercial innovations. While maintaining the growth in technology, the United States expects to secure industrial production as well.

To maintain the United States' access to space, it set regulations to primarily focus on the use of domestic capabilities. They do not want to rely on foreign launch capabilities. This consist of increasing the United States efficiency and cost on launch vehicles and technologies. This includes maintaining and enhancing space-based positioning, navigating, and timing systems like GPS.

To achieve its goals of maintaining its leadership, the United States expects its agencies to develop and retain space professionals by promoting career progression and other educational developments in the STEM fields. This will also improve space system development and procurement. The United States also plans to strengthen partnerships through cooperation between agencies and institutions and the sharing of assets that will promote innovation.

With the increase in use of space for critical infrastructure and various technologies, the United States wants to ensure those areas are protected and relies on the Secretary of Defense, Homeland Security, and National Intelligence to stay connected and focused on threat and risk assessments.

International Cooperation

The United States will strengthen its leadership in space by a show of power and deterrence; promoting the safe and stable use of space; and by combining mutual interest with allies and other nations in group efforts of self-defense and other areas where international cooperation is beneficial for the United States' goals.

Preserving Space

The United States set up guidelines which they believe will promote the safe, stable, and long-term sustainability of space activities. This includes setting up standards and policies to promote and ensure no parties are acting in a manner that will jeopardize the use of space. The United States will pursue the sharing of space situation awareness data throughout government and commercial agencies.

The United States foresees a focus on space debris. With the creation of new policies to limit the creation of new debris but also pursue debris removal, this will allow for a safe and more long-term use of space. They insist that all nations foster the development of best practices to prevent any orbital collisions by mitigating the creation of debris.

Export Policies

With the exploration of space comes the discovery and accumulation of materials. The United States sets guidelines on how technologies and materials should be traded and exported. This will include licenses and following various guidelines. Though exporting is encouraged for cooperations, it will only be done when it does not threaten the national interest. This creates a loophole as no nation is allowed to claim anything in space, but private cooperations can.

Nuclear

These sections emphasize the use and discovery of technologies that should be allowed and protected. The United States will develop and use nuclear power and propulsion systems where such systems will help achieve the goals of the nation.

Protection of Electromagnetic Spectrum

The United States will also focus on its protection of the electromagnetic spectrum in various steps. This includes making sure all users focus on preserving and protecting the spectrum by setting up regulatory approval for various actions.

Cyber Security and Critical Function

With the use of space for satellites and various technologies, the United States will be focusing on the security of those systems by preventing unauthorized access, collaboration with interagency, allies, and partners, and adopting best practices and standards in the creation of rules and regulations.

The United States will also pursue efforts to enhance the protection and security of its infrastructure by conducting periodic exercises to test the continuity of national critical functions.

Sector Guidelines

The United States conducts space activities in three distinct sectors. This includes commercial, civil, and national security.

The commercial space sector guidelines refer to goods, services, and activities provided by various sectors. The commercial space sector in the United States leads the global space marketplace and is critical to national strategic objectives such as increased and sustained prosperity, free market principles, enhanced international partnerships and collaboration, technological innovation, and scientific discovery, as well as US and allied security.

Civil space guidelines focus on the science, exploration, and discovery aspects of space. The United States should lead an innovative and sustainable program of scientific discovery, technology development, and space exploration. Beginning with missions beyond low Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization. These missions include a program to set foot on the moon again, continuing participation in the ISS, and continuing to grow partnerships within the space sector. The United States will still use space as a tool for observation of the Earth's surface, environment, and weather.

The Nation Security Space guidelines focus on the security and possible warfighting domain because of competitors. This section lays out the framework and reasons why the development of the United States Space Force is necessary. It goes into details on the use of space for strategic, operational, and tactical intelligence that helps give the United States a military advantage, why these assets need to be protected, and lays out the guidelines for the Secretary of Defense and the Director of National Intelligence.

Van Allen Belts

A Van Allen radiation belt is a zone of energetic charged particles, originating mostly from solar winds that are captured by and held around planets by magnetic fields. The Earth currently has an inner and outer belt that protect the Earth's atmosphere. The outer belts consist mostly of electrons, while the inner ones contain mainly protons. Though the belts protect the Earth, venturing into them can result in unwanted radiational damage. (Fox, 2014)

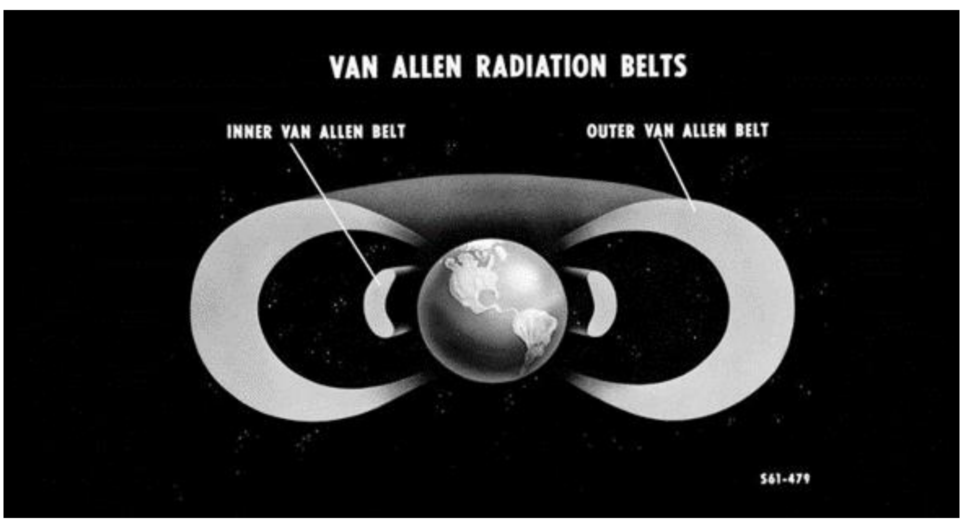

Figure 1 : Van Allen Radiation Belts

Credits: NASA's Goddard Space Flight Center/Historic image of Van Allen Belts courtesy of NASA's Langley Research Center

The belts themselves can shrink, grow, or even sperate into a 3rd belt. Generally, the inner belt stretches from 400-6,000 miles and the outer belt from 8,400 to 36,000 miles above Earth's surface. Along with the belts, there is another particle cloud called the plasmasphere, which starts around 600 miles to some overlap of the outer belt. The plasmasphere has a characteristic that slightly scatters the highly charged electrons away from Earth. This scatter can be attributed to the characteristics of the electrons coming towards Earth, as they tend to slow down to a gentle drift, allowing the plasmasphere to push them back. (Fox, 2014)

Lunar Gateway

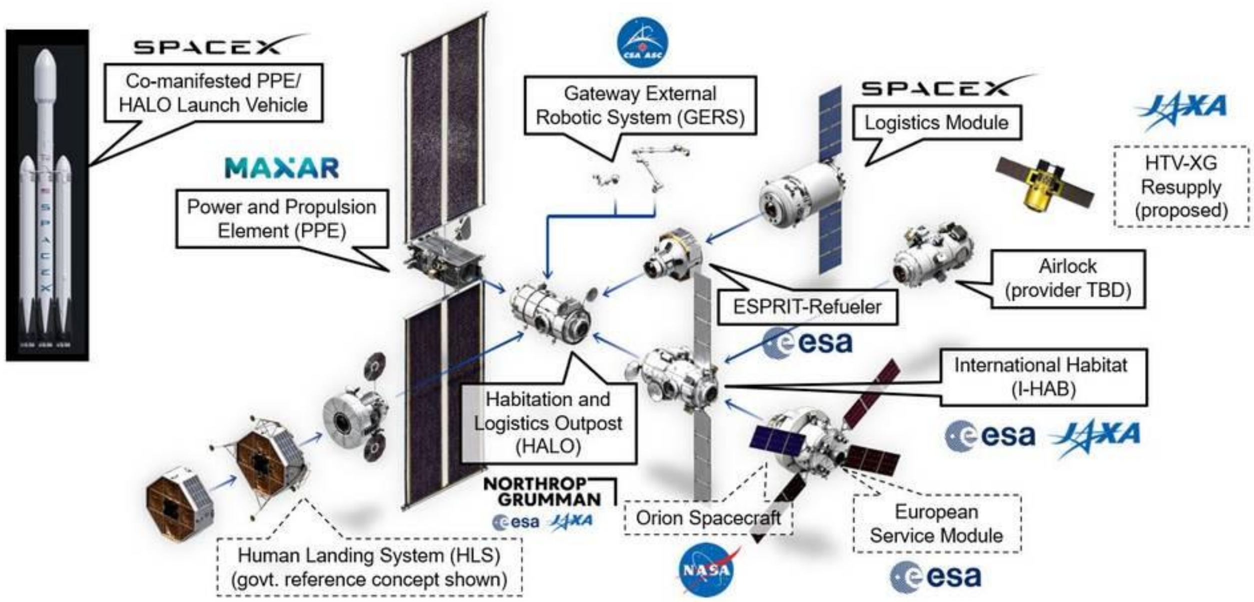

Figure 2: The Lunar Gateway

Source: "Multilateral Coordination Board Joint Statement" (2019)
Retreived from https://www.nasa.gov/feature/multilateral-coordination-board-joint-statement

NASA and the Canadian Space Agency (CSA) are planning to create a new space station that would act as a critical outpost and staging grounds for astronauts for space exploration orbiting the moon for NASA's Artemis program. The Gateway is set to be launched by SpaceX's Falcon Heavy rocket in November 2024. The first phase of the Gateway will consist of only two modules, the Power and Propulsion Element (PPE) and the Habitation and Logistics Outpost

(HALO). (Ackerman, 2022) Phase two would consist of multiple modules being connected to the Gateway to provide numerous capabilities that would be essential for lunar permanence.

The objective of the Power and Propulsion Element will be to provide the Gateway with power, communications, control, and orbital transfer capabilities. Maxar Technologies was awarded this $375 million contract by NASA to develop and demonstrate these capabilities. (Russell, Anderson, & Incian, 2019) The PPE is a high-power, ~60-kW solar electric propulsion system. This makes this propulsion system roughly three times more powerful than current capabilities. The Power and Propulsion manager, Mike Bennet, stated that the method of propulsion of this system is "extremely efficient and requires much less propellant than a traditional chemical system, allowing the Gateway to move more mass around the moon". A key attribute is that a solar electric propulsion system has the capability to be fired for years at a time while also being able to turn on and off and adjust thrust to allow high mobility of the space craft. (Russell, Anderson, & Incian, 2019)

The Habitation and Logistic Outpost will be the main cabin for the crew of astronauts who will be visiting the Gateway. Its primary capability will be to provide basic life support while the crew prepares for a lunar visit. "It will also provide command, control, and data handling capabilities, energy storage and power distribution, thermal control, communications and tracking capabilities, as well as environmental control." (Mars, 2022) The Gateway is being designed in a way such that it is highly modular. The HALO will have multiple docking ports for the potential to connect future modules and vehicles. The company awarded this $187 million contract to Northrop Grumman Space.

The Gateway will be able to adjust its position in a variety of orbits around the moon, allowing full access to the lunar surface. With the initial plan to explore the southern pole of the Moon, the Gateway will be using a Near-Rectilinear Halo Orbit (NRHO). NRHO allows the Gateway to swoop down near the southern pole of the moon for a convenient descent to the lunar surface to access NASA’s Artemis lunar base while taking advantage of Distant Retrograde Orbit (DRO) to preserve fuel. DRO preserves fuel as it takes advantage of the planet-moon gravitational pulls to balance the forces to maintain stability in this orbit, allowing the spacecraft or object to reduce its energy expenditure. The range of the NRHO orbit from the moon would be 1,860 miles at its closest to 43,500 miles when in DRO. (Zaid, 2022)

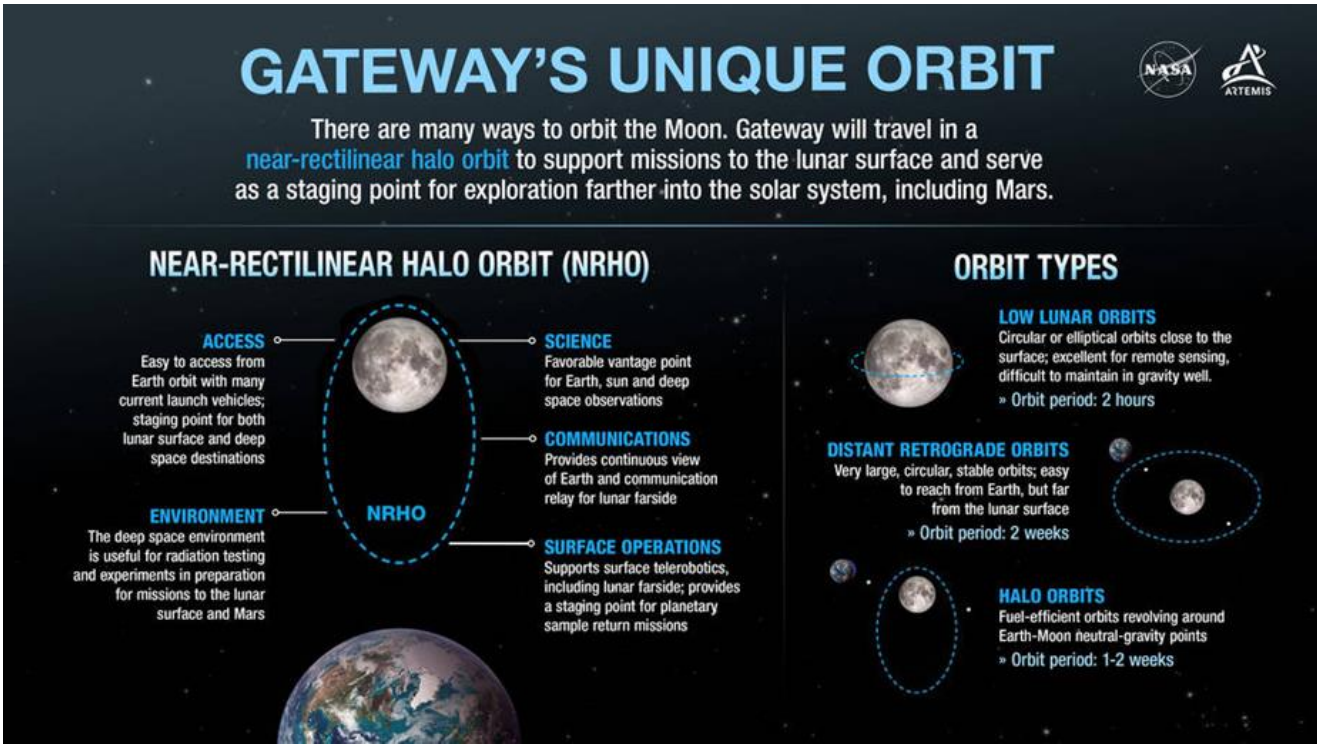

Figure 3: Near-Rectilinear Halor orbit (NHRO)

Source: "A Lunar Orbit That's Just Right for the International Gateway" (2022)
Retreived from https://www.nasa.gov/feature/a-lunar-orbit-that-s-just-right-for-the-international-gateway

NASA plans that the Gateway station would be run completely autonomously for up to 11 months out of the year and would only have ground operation support for 8 hours a week. This is partially because the price of launching to lunar orbit is vastly more expensive than just to low Earth orbit and the uncertainty of the effects of radiation outside the Van Allen Belts, which act as protection for Earth and the International Space Station from harmful radiation. To successfully reach this goal, NASA plans to use a combination of smart computers that can handle any issue it can through software, while robotic systems can handle physical issues. Initially, this station will be used to conduct investigations and data collection on radiation and space weather. Due to the high priority of these concerns, the first two payloads transported to the Gateway will consist of radiation and space weather instrument suites. (About Canadarm3, 2022)

Currently, an issue is that the technology for the robotic system does not exist fully yet. Both NASA and CSA are relying on industry partners like MDA. MDA currently has the robotic arm Canadarm2 working on the ISS but plans to create a multi-robot version, Canadarm3. This new version would consist of a large arm (8.5 m) that can handle bigger tasks, along with a smaller, dexterous arm. These arms would be able to move around and reconnect to different points of the station, making these stationary arms mobile. (About Canadarm3, 2022)

Figure 4: Canadarm3

Source: “Government of Canada: Canadarm3, Canada’s Smart Robotic System for the Luanr Gateway” (2020)
Retreived from https://www.asc-csa.gc.ca/eng/multimedia/search/image/watch/16533

A possible future utilization of the Lunar Gateway and Artemis Lunar Base would be to mimic space travel to Mars. Astronauts would be able to stay on board the Gateway for an extended period to mimic travel time to Mars. Then they proceed to land and use the lunar base to simulate landing on Mars, where they can perform tasks on the lunar surface. From there, they will travel back to the Gateway, where they will stay for the simulated journey back. This allows for important data to be gathered on the mental and physical states of the astronauts from this length of isolation and radiation intake.

Artemis

The Space Policy Directive 1 states the United States' purpose is to "lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations." (Smith, Merancy, & Krezel, 2019) To stay consistent with this goal, NASA initialized the Artemis program. The Artemis program will bring humanity farther into deep space than we have ever been, starting with a revisit to the Moon and then to Mars. This intrepid goal is going to need cooperation from not just domestic commercial companies but multiple partners around the world.

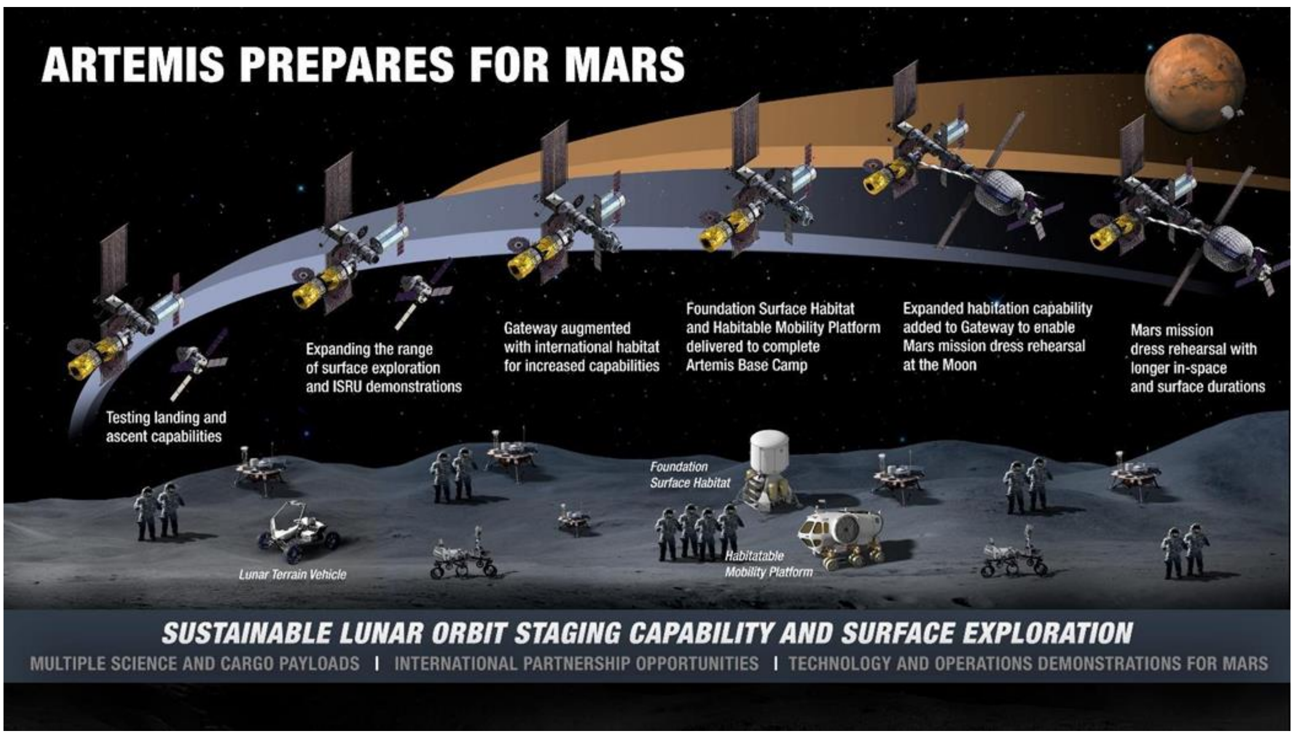

Figure 5: Artemis Mission Plan

Source: "NASA Outlines Lunar Surface Sustainability" (2020)
Retreived from https://www.nasa.gov/feature/nasa-outlines-lunar-surface-sustainability-concept

As stated in the Artemis Plan, "We need several years in orbit and on the surface of the Moon to build operational confidence for conducting long-term work and supporting life away from Earth before we can embark on the first multi-year human mission to Mars. The sooner we get to the Moon, the sooner we get American astronauts to Mars." (Artemis Plan, 2020) To maintain US leadership in space, we must act quickly, resulting in this ambitious space program with a crew lunar landing by 2024 and lunar permanence by 2028.

The initial goals set forth consist of the following: In 2021, commercial lunar payload services will deliver 16 scientific instruments to the lunar surface that will help collect important data. Next, the Volatiles Investigating Polar Exploration (VIPER) rover will investigate the lunar polar soil’s permanently shadowed areas for data samples about the concentration of various volatiles. Next, to prepare for the Gateway lunar space station, small CAPSTONE CubeSat satellites will be launched into Near Rectilinear Halo Orbit (NRHO) around the Moon to help with predictive models about this new orbit. Artemis I, an uncrewed mission utilizing the Space Launch System rocket and Orion, will commence a test flight to verify their capabilities. Gateway’s PPE and HALO will be launched into its NRHO around the moon. Artemis II will be a 10-day crewed test flight that will set the record for the farthest human travel from Earth, validating deep space communication and other systems. Finally, in 2024, Artemis III, astronauts will embark on Orion to the Moon, this time reaching the lunar surface with the help of the Human Landing System.

To achieve the ambitious goals of the Artemis program, NASA needs technology to match. The Space Launch System (SLS), a super heavy-lift rocket, is the world’s most powerful rocket to date. Due to its unmatched capabilities, it is the only rocket capable of sending astronauts, the Orion Space Craft, and supplies directly to the Moon and beyond. (NASA's Space Launch System, 2022) The SLS will use five segmented solid rocket boosters with a total thrust of 3.6 million pounds and four liquid-fuel RS-25 engines with a total thrust of 418 thousand pounds at sea level and 512 thousand pounds at vacuum. The 212-foot, newly developed core stage consists of propellant tanks, avionics, and equipment. For in-space propulsion, the SLS will be using an Interim Cryogenic Propulsion Stage (ICPS). The ICPS is a single Aerojet Rocketdyne RL10 engine utilizing liquid hydrogen and oxygen system that can produce almost 25,000 pounds of thrust. (NASA's Space Launch System, 2022) Along with carrying the Orion, the SLS will have a large payload list of electronics from various companies to conduct experiments that can be seen in the supplied appendix. (NASA's Space Launch System, 2022) The SLS will be evolvable throughout the phases to adapt to the needs of the Artemis program.

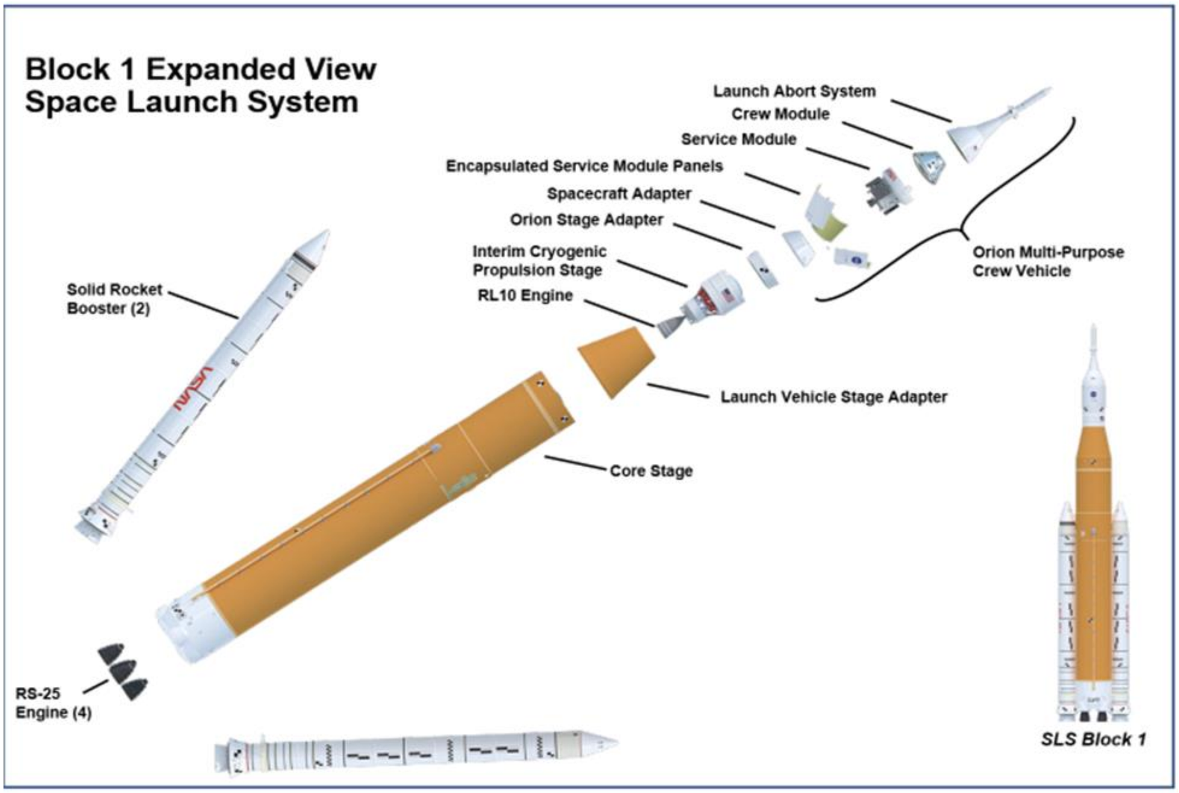

Figure 6: The Space Launch System

Source: "NASAfacts Space Launch System" (2021)
Retreived from https://www.nasa.gov/sites/default/files/atoms/files/sls_fact_sheet.pdf

Atop the SLS, NASA created a new top-of-the-line exploration spacecraft, the Orion, capable of deep-space missions. "Named after one of the largest constellations in the night sky and drawing from more than 50 years of spaceflight research and development, the Orion spacecraft is designed to meet the evolving needs of our nation's deep space exploration program for decades to come." (NASA, 2022) The Orion's service module will be the main supplier of power, propulsion, thermal control, air, and water to the crew. This module consists of a main engine, eight auxiliary engines, and 24 reaction control thrusters. The Orion system will utilize four seven-meter-long solar wings that will be able to rotate and pivot to track the sun, supplying 11 kW of power. The Orion Crew Module (CM) is capable of housing up to four astronauts, with the powerful block Avcoat heatshield rated to withstand the lunar return of up to 5000 degrees Fahrenheit. (Smith, Merancy, & Krezel, 2019) Finally, the Orion will be equipped with a Launch Abort System (LAS), capable of millisecond reaction in case of emergencies. The LAS abort motor is capable of 0–405 MPH in 2 seconds with 400 k lbs. of thrust. The LAS will also have a jettison motor that will separate the LAS from the crew module and an attitude control motor with eight valves used to steer the LAS. (NASA, 2022)

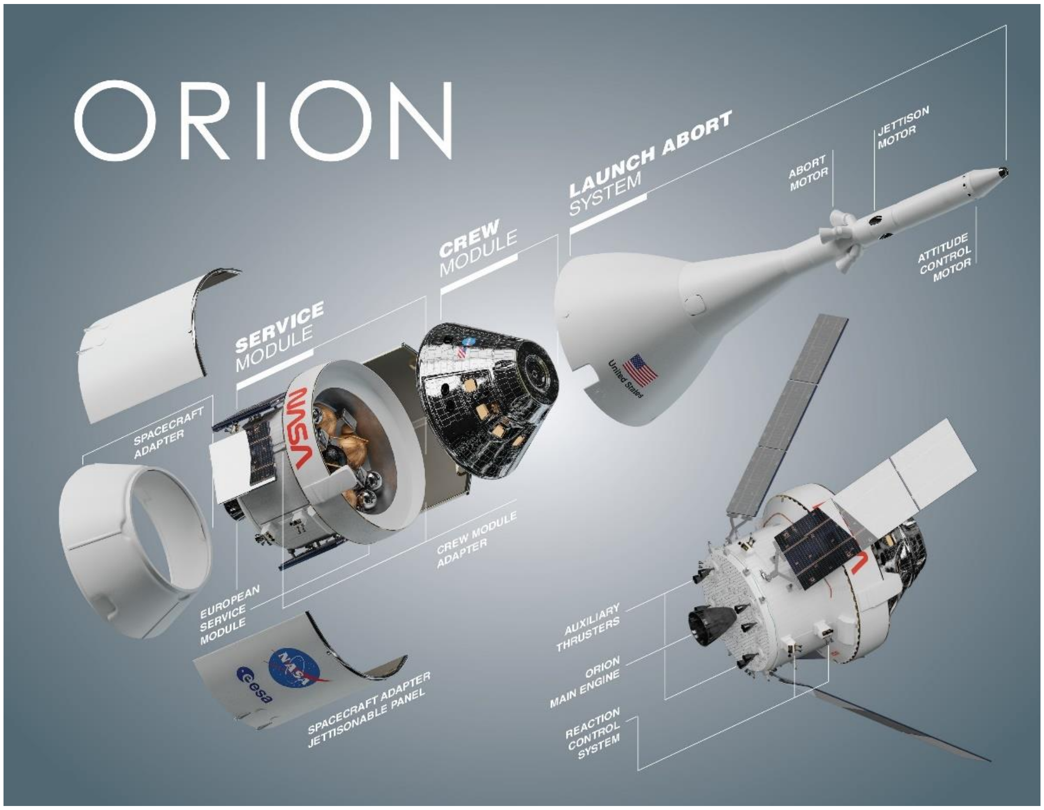

Figure 7: The Orion

Source: "Aerojet Rocketdyne: Safely Carrying Humans to Deep Space" (2021)
Retreived from https://www.rocket.com/space/human-exploration/orion

Artemis I

Artemis I will be a 4-to-6-week uncrewed integrated flight of the Space Launch System (SLS) with the Orion. This launch is unmanned, and this flight will be carrying data-gathering tools needed to validate the performance and deep space and reentry capabilities of these systems, laying the foundation for future exploration. (Artemis Plan, 2020)

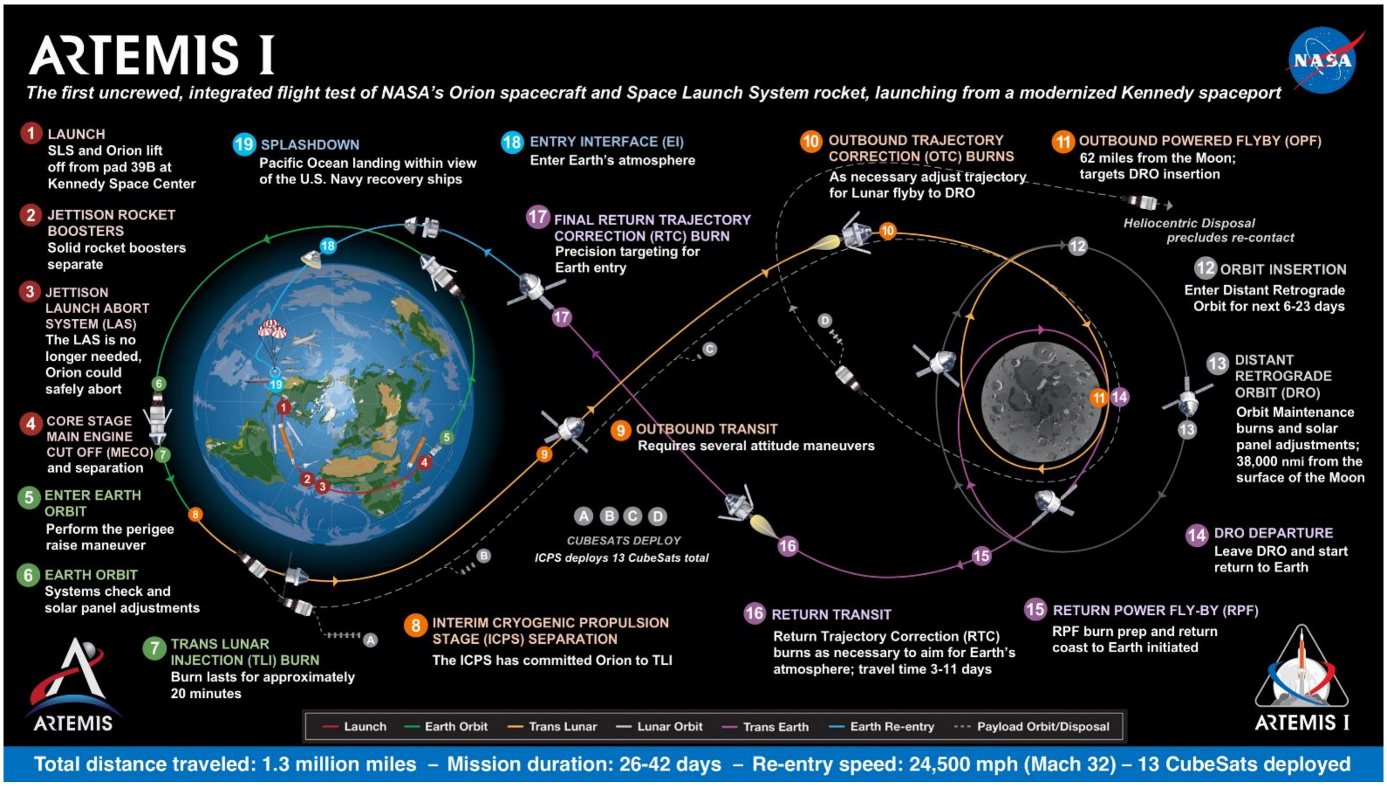

Figure 8: Artemis I

Source: "Artemis Mission Phases" Credit: NASA
Retreived from https://exploredeepspace.com/deep-space-mission/artemis-missions/

The launch will take place at the spaceport at the Kennedy Space Center. To perform liftoff, the SLS rocket will produce 8.8 million pounds of thrust. After the final boosters are finished, the core of the SLS will detach from the Orion. Once Orion is in orbit, it will utilize its Interim Cryogenic Propulsion Stage (ICPS) to provide TLI burn. At around the 2-hour mark, the Orion will then separate from the ICPS. Once detached, the ICPS will launch the thirteen CubeSats provided by companies across the world to perform experiments and data collection.

On its way to the Moon, the Orion will be utilizing its Encapsulated Service Module panels to provide power and propulsion to the Orion. On this path, the Orion will pass through the Van Allen Belt, making it in the danger zone of harmful radiation. This is when the mission of Artemis I starts to be achieved. The Orion will be demonstrating its ability to navigate and communicate in deep space on its several day trip to the Moon's orbit. The Orion will utilize the Moon's gravitational force to place itself in a new deep retrograde for six days to collect important data and allow mission controllers to assess the performance of the Orion.

For the Orion's return, the Orion will utilize the Moon's gravitational force and a precisely timed firing of the ESM to slingshot the Orion back to Earth at about 25,000 miles per hour. This is where the Orion's new heatshield will be tested fully for lunar entry conditions of approximately 5,000 degrees Fahrenheit. The landing zone for the Orion is planned to be off the coast of Baja, California, where a recovery ship will be stationed for retrieval. (Smith, Merancy, & Krezel, 2019)

Artemis II

Artemis II will be using the data and experience collected from Artemis I to send four crew members on a 10-day trip around the Moon. This would be a record for the farthest travel by humans from Earth. This will validate the support systems protecting astronauts for deep space travel. After the SLS launch, it will orbit Earth twice before setting a trajectory for the Moon.

After reaching High Earth Orbit (HEO), the Orion will separate from the ICPS. Using the ICPS as a target, the astronauts will conduct a proximity operation demonstration. During this demonstration, the astronauts will manually drive the Orion to assess its handling and mobility for future manned missions. Once finished, control will be given back to mission control.

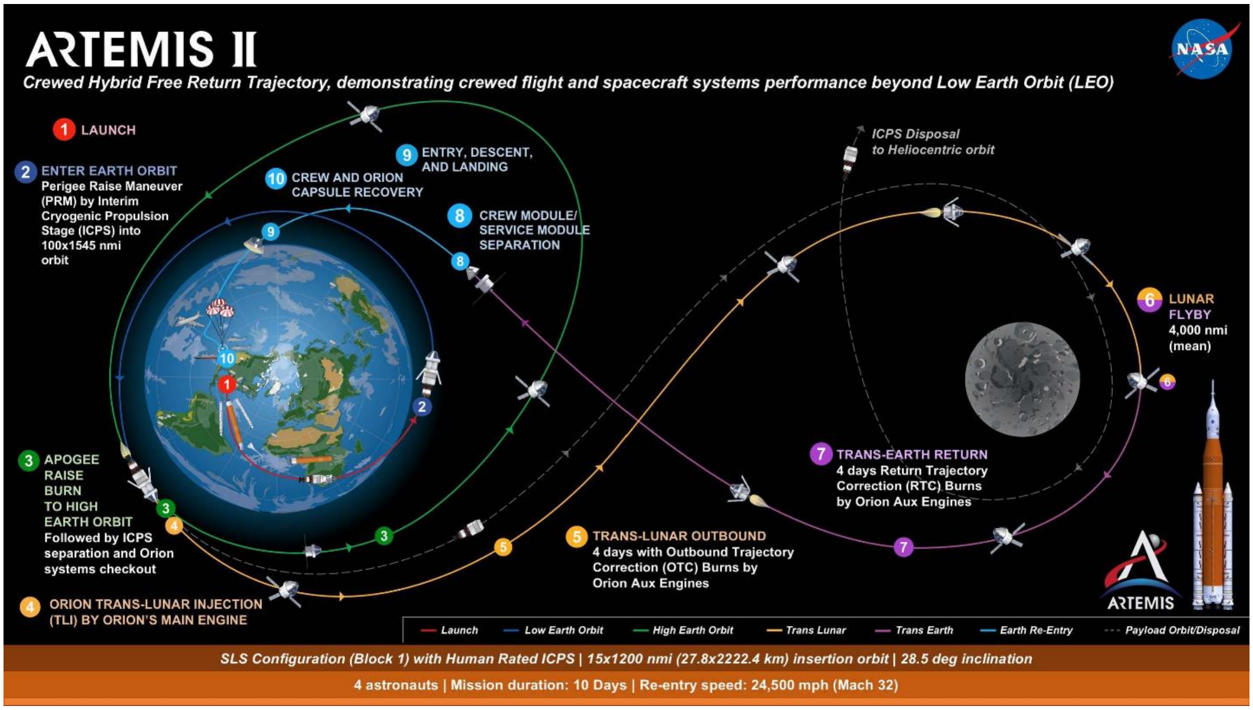

Figure 9: Artemis II

Source: "Artemis Mission Phases" Credit: NASA
Retreived from https://exploredeepspace.com/deep-space-mission/artemis-missions/

While in HEO, the important performance of the life systems will be assessed. Once these systems are noted to be performing to their desire, the crew will exit their space suits and remain in plain clothes until reentry and recovery. Once in HEO, it takes only a fraction more energy to reach past translunar injection and reach lunar orbit. The Orion will be using its Service Module (SM) for this last push. This maneuver will send the Orion and its crew around the outside of the Moon. After its initial orbit, the Orion will use the Earth's gravity to perform a fuel-efficient trajectory back home.

Due to our experience in space travel and on the ISS, NASA is aware of the spaceflight-induced skeletal muscle atrophy due to microgravity. Although this mission will only last 10 days, further exploration into deep space will have more drastic effects on the astronauts. To mitigate these issues on Artemis II and future launches, the astronauts will follow a strict exercise regimen proven and built on decades of experience. The exercises are designed to "produce the highest levels of carbon dioxide and water vapor in the cabin, demanding the life support system to maintain proper cabin atmospheric conditions that will further verify the spacecraft's life support system performance." (Artemis Plan, 2020)

<u>Artemis III</u>

Artemis III will take all the experience and data collected from Artemis I and II and perform one of the most ambitious launches of a crewed ship to date. Using the SLS and Orion, four crew members will once again embark towards the moon in 2024, this time to set foot on the surface once again.

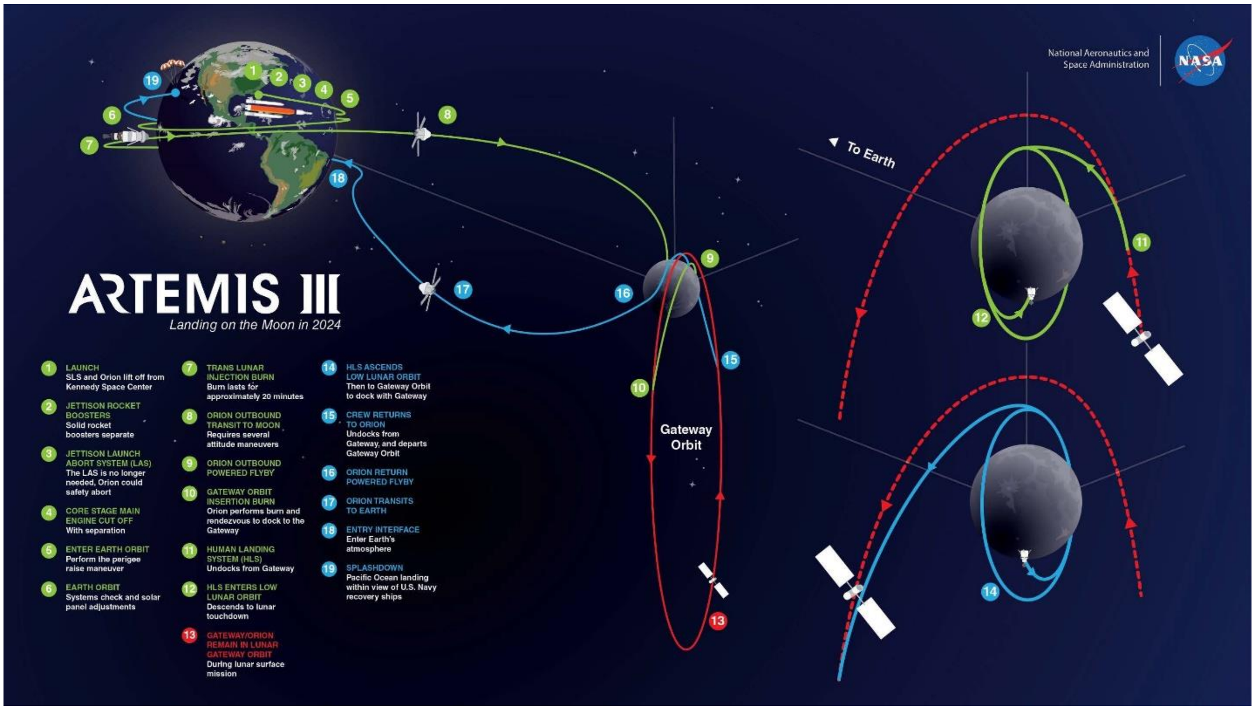

Figure 10: Artemis III

Source: "Artemis Mission Phases" Credit: NASA
Retreived from https://exploredeepspace.com/deep-space-mission/artemis-missions/

To make this mission possible, Artemis III will be utilizing more components than the earlier missions. Once in orbit around the moon, Artemis III's Orion will dock with the newly developed space station, the Gateway. The Gateway will act as the team's staging point before surface missions. This system set up will provide critical operational confidence in how future Mars missions will be operated. Having the ability to stay in orbit around the Moon or Mars can drastically extend operation time, allowing for more experiments and data collection. Once the crew is on the Gateway, they will have four days until the first opportunity to head back home occurs, but if the mission is running smoothly, they plan to depart back home in seven-day increments. (Smith, Merancy, & Krezel, 2019)

Artemis III will be using the Human Landing System (HLS). The HLS will be the transportation vehicle from the Gateway to the Moon's Lunar Base and back. This system will be able to dock to the Orion or the Gateway for various mission situations. The HLS and the included Integrated Lander Vehicle (ILV) will be co-created by Blue Origin, Lockheed Martin, Northrop Grumman, and Draper. (Artemis Plan, 2020)

While the astronauts are on the surface of the moon, NASA requires a minimum of two space walks, but prefers as much as possible. This is where they will be performing experiments and collecting more data and samples to bring back to Earth. With these samples, we can get a better understanding of the geology of the Moon, help collect important data on sequences of impact events, and characterize the dispersion of volatiles inside and outside of permanently shadowed areas. (Artemis Plan, 2020)

Artemis Base Station

NASA's Artemis program is a multi-step process that will lead to human exploration of space, starting with the Moon again and then Mars. This program also includes the Lunar Gateway, which acts as the staging point for lunar missions. Along with Gateway, there will be the Artemis Base Camp at the Lunar South Pole.

The Artemis Base Camp will consist of three elements: a "Lunar Terrain Vehicle (unpressurized rover) to transport suited astronauts around the site; the habitable mobility platform (pressurized rover) that can enable long-duration trips away from Artemis Base Camp; and the foundation surface habitat that will accommodate four crew on the lunar surface". (Artemis Plan, 2020) Though this is an ambitious and new step for space exploration, this will also be a testing area for new technology that will help extend the reach of humanity into further space exploration and occupation.

The potential staging grounds for the Artemis base are still under evaluation. One area mentioned is the Shackleton Crater, which lies at the southern pole of the Moon.

Though this is only an initial position, the Artemis mission will be heavily reliant on mobility. One of the reasons for a lunar base is resource discovery and collection, making mobility essential due to the dispersion of these resources. (Artemis Plan, 2020)

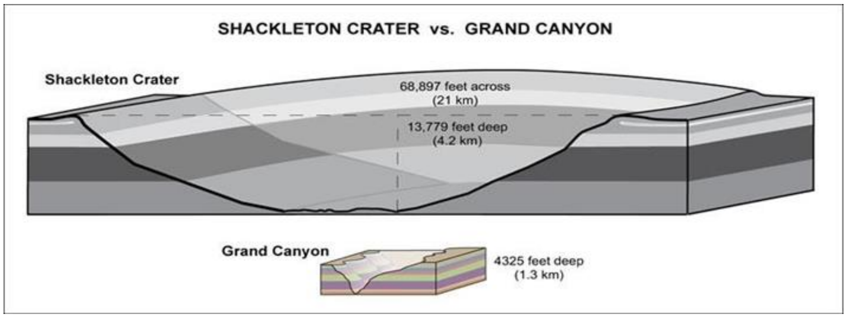

Figure 11: Shackleton Crater

Source: "Lunar and Planetary Institute: Lunar South Pole Atlas." (2019)

Retreived from https://www.lpi.usra.edu/lunar/lunar-south-pole-atlas/

As stated earlier, a major concern is the radiation the astronauts will have to endure in space. Though we do not have a perfect solution yet, astronauts on the lunar surface will have access to better solutions. Unlike astronauts in a space craft, there are a lot more ways to put more mass between you and the incoming particles. These solutions can include underground bunkers on the moon, or other forms of shelters that can be built ahead of time. With the high mobility of the Artemis program, timing is crucial. NASA's Community Coordinated Modeling Center is working on the prediction of solar explosions, this will allow the astronauts to have enough time to take the appropriate actions in such events. Bunkers utilizing lunar regolith leads to a few issues, it would require an extensive amount of material to be moved and reduces mobility of the mission.

Table 1: Exposure Limits for Atronauts by NASA

Career Exposure Limits for NASA Astronauts by Age and Gender*				
Age (years)	25	35	45	55
Male	1,500 mSv	2,500 mSv	3,250 mSv	4,000 mSv
Female	1,000 mSv	1,750 mSv	2,500 mSv	3,000 mSv

Source: "Space Faring: The Radiation Challenge."

Retreived from https://www.nasa.gov/sites/default/files/atoms/files/sf_radiation_stu_bob.pdf

Not only is radiation an issue, but micrometeoroids present a major design consideration for a lunar base. Due to the moon lacking an atmosphere to disintegrate meteoroids, there is a chance of a meteor impacting a lunar base module at high velocities. " A typical proposed approach is to provides an exterior β-cloth fabric layer with an interior Nextel/Kevlar blanket over a shelter The required shield mass is estimated to be 10 kg/m^2. (Bell & Bannova, 2011) To mitigate any extra mass, meteor protection can be combined with radiation protection.

Table 2: Recommended NCRP Radiation Dose Limits

Organ	30-day limit	1-year limit	Career
Lens[a]	1,000 mGy-Eq	2,000 mGy-Eq	4,000 mGy-Eq
Skin	1,500	3,000	4,000
BFO	250	500	Not applicable
Heart[b]	250	500	1,000
Central nervous system (CNS)[c]	500	1,000	1,500
CNS[c] ($Z \geq 10$)		100 mGy	250 mGy

[a]Lens limits are intended to prevent early (<5 years) severe cataracts (e.g., from a SPE). An additional cataract risk exists at lower doses from cosmic rays for subclinical cataracts, which may progress to severe types after long latency (>5 years) and are not preventable by existing mitigation measures; however, they are deemed an acceptable risk to the program.

[b]Heart doses calculated as average over heart muscle and adjacent arteries.

[c]CNS limits should be calculated at the hippocampus.

Table 3: Recommended Micrometeroid Protection Based on the ISS Meteroroid and Orbital Debris System (MDPS) Design

Description	Material	Area density (kg/m^2)
Front bumper	Kevlar composite fabric 0.25 cm thick-5 layers of 300 g/m^2 Kevlar fabric	1.5
Rear Bumper	Nextel 0.30 cm thick	2.8
	Kevlar 0.64 cm thick	4.0
Spacer		1.7
Total		10

Table 1 & 2 Source: “Lunar Habitat Micrometeoroid and Radiation Shielding: Options, Applications, and Assessments” (2011) Retreived from https://sicsa.egr.uh.edu/sites/sicsa/files/files/publications/asceaerospacejournalarticle_0.pdf

Debris Concern

Artemis missions I to III overarching theme will be to set up the foundation for lunar permanence, to take full advantage of the lunar surface for new discoveries, and more training for a farther and longer journey to Mars. To accomplish this task, it is going to take cooperation between agencies and nations, and even more cooperation and innovations to keep it sustainable.

A foreseen issue that was a focus of the United States Space Policy was maintaining a safe and long-term use of space. The United States declared a priority to reduce and clean up space debris in order to reduce the risk of trajectory collisions. (National Space Policy of the United States of America, 2020) As stated in an interview for the Nation Space Association with Ben Reed, Co-Founder & CTO of Quantum Space, and figures from NASA, empty cargo modules would be sent into a graveyard orbit, and the ICPS from Artemis missions are planned to be sent on a heliocentric disposal. The heliocentric orbit sends the objects into close proximity to the Sun. I am worried that with time and due to attempted sustainability, that would result in a graveyard orbit around the Moon similar to what we have around Earth. The graveyard orbit around Earth is roughly 22,400 miles above its surface, resulting in the debris being about 200 miles above the farthest active satellite. (Ashish, 2022) Though it places the debris above active satellites, space travel trajectories will have to be planned to avoid this debris.

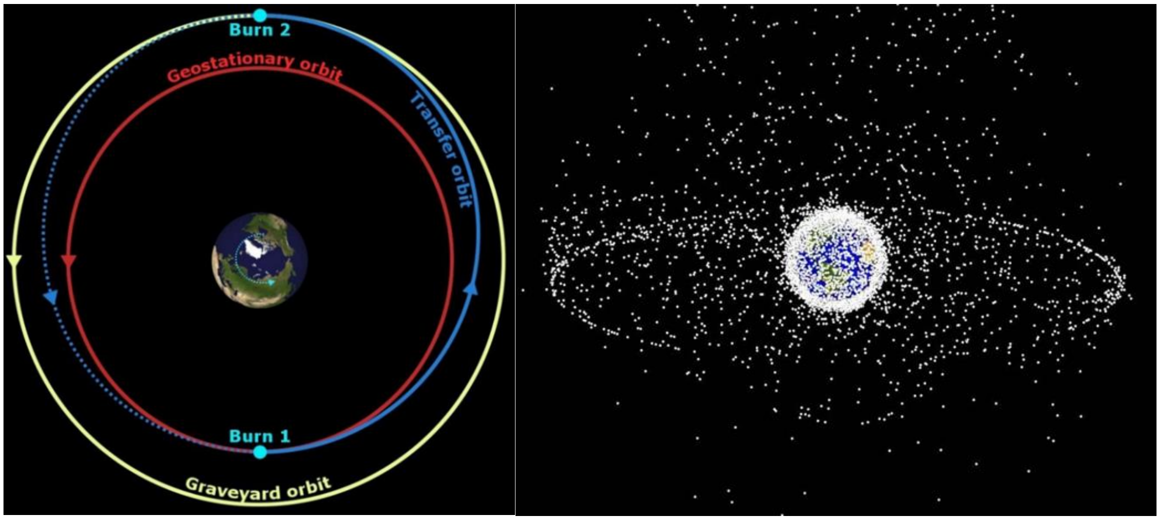

Figure 12: Graveyard Orbit and Space Debris
Graveyard orbit (Left) and Registered Space Debris (Right)

Source: "ScienceABC, Graveyard Orbit" Credited : NASA
Retreived from https://www.scienceabc.com/nature/universe/graveyard-orbit-what-happens-when-artificial-satellites-die.html

During the early days of space exploration, little thought was given to the problem of space debris. Space debris is a serious issue, especially with hopes of maintaining space exploration safely. There are currently two ways to dispose of satellites and other objects we are sending into space. For objects farther from Earth, this results in adjusting their trajectory to place them in a graveyard orbit. This option is also more energy efficient as it only "requires a delta-v (change in the velocity of the satellite) of only 11 m/s (36 ft/s), whereas de-orbiting requires a change of about 1,500 m/s (4,900 ft/s)". This orbit results in the debris lasting hundreds of years. This poses a huge risk as the debris accumulation occurs. It will drastically minimize launch windows due to the fear of collision with launching rockets or other space exploration vehicles. The second option is to lower the altitude of the objects to have them slowly burn in the Earth's atmosphere completely or land the last bits in remote areas. (Ashish, 2022)

The problem occurs in the sustainability of a lunar permanence, as we will soon have satellites and multiple payloads being transported to the Moon's orbit. With no atmosphere to burn the debris up at a lower orbit, all debris will need to be sent to a graveyard orbit. This will result in a harder time maintaining sustainability as more space debris will soon pose a risk for these types of launches. It becomes paramount that we expedite the idea of how to properly dispose of or mitigate the production debris in lunar orbit. Forming these strict guidelines, as we currently have set for Earth, as seen in the Orbital Debris Mitigation report by NASA, will be a proactive step necessary to preserve a positive and safe space presence around the Moon and beyond. (Kelley, Jarkey, & Stansbery)

CHAPTER 3: DISCUSION AND ANALYSIS

United States Space Policy Analysis

The United States will create an environment that energizes our industry to create innovative commercial approaches that will carry and sustain our next generation of explorers and entrepreneurs on the Moon and then on to Mars and beyond.

- The Policy lays out guidelines for Civil Space sector
    - Handles the science, exploration, and Discovery.
    - Enables human expansion across the solar system.
- Lead a program to on the Moon by 2024, followed by a sustained presence on the Moon by 2028, and the subsequent landing of the first human on Mars.
- Maintain a sustained robotic presence in the solar system, map and characterize water, mineral, and elemental resources; and demonstrate new technologies.
- The United States will pursue the extraction and utilization of space resources in compliance with applicable law, recognizing those resources as critical for sustainable exploration, scientific discovery, and commercial operations.
- Increase the quality of life for all humanity through the cultivation, maturation, and development of space-enabled scientific and economic capabilities, including space and Earth resource discovery, management, and utilization.

The United States mission is to expand its reach. Not only for America but for all humanity. This report focuses on the creation of a presence on the moon to mine for Helium-3 and the advantages a Moon colony holds. Helium-3 with the right technology has the capabilities to help with the current energy crisis by being utilized as a sustainable energy source. It will highlight the element and its use in a fusion reactor. Along with a plan of presence of workers on the moon in aid of mining such element.

As noted above from the United States Space Policy, they plan to travel to the moon with in the next two years, with a sustained presence on the moon by 2028. This will require a strong infrastructure on the moon, such as a command base and possible outposts. With the cooperation between a robotic system, we can get a better understanding and mine for the element Helium-3.

Stated on page 6 of the Space Policy, one of the goals of the United States is to acquire new resources that will help aid in increasing the quality of life of all humanity. With fossil fuels as our primary source of energy depleting, we need an alternative if we are going to continue to survive. This alternative being helium-3.

To achieve these goals of a steady presence on the moon, the United States set up guidelines to stay on track and make progress. This includes promoting STEM fields to help aid in the increase of technologies and encourage commercial space innovation. On page 8, it states, "enhance operational efficiency, increase capacity, and reduce launch costs by investing in the modernization of space launch infrastructure." This, I believe, would be paramount in aiding the constant travel between the Moon and Earth. The United States would need to transport workers, supplies, and resources back and forth. If we do not lower the cost of launches, this will be too expensive of a market to maintain.

The policy then focuses on promoting private industries. I think this might be a viable option to lower the cost of launches, as Space-X has created and tested reusable rockets, drastically lowering the cost of each launch. One issue I foresee would be a single company controlling the market. With a private industry holding the sole access to the energy source, I would be unsure what their intentions would be with increasing prices and exporting said material to various nations. There is also the issue of foreign countries who are not exactly allies with us being strong competitors like China who has been probing the moon to learn more about Helium-3. With this, it is important for the United States does act fast to try and maintain a leader in this technology. Although the government having sole access to it might also be an issue, I believe there are more ways to oversee and regulate what is going on when it is our own country, through a direct government agency as there is more interagency cooperation holding other agencies to a certain standard.

In all, I am excited about what lies ahead and the market opportunities and life opportunities that will be created from the exploration of space. I do strongly believe and agree that space holds discoveries that will help better life on Earth and even life in space. I am confident in the advatages Helium-3 is capable of in different scenarios. I feel more at ease knowing that the United States' space policy was thorough. It discusses the acquisition of materials, how items would be traded and exported, and how we are establishing strong defense infrastructures to protect ourselves and allies from various threats; as well as the push to create a safe, stable, and long-term environment for space.

Space Station and Van Allen Belt

The ISS is current orbit is approximately 254 miles above the Earth’s surface. This allows the station and astronauts to be protected by these belts. The issue is that the Lunar Gateway station will not be. The average distance of the moon from Earth is 384,400, making anything orbiting the moon and, on the surface, susceptible to harmful radiation. Currently, this is a high priority for NASA to figure out. Therefore, the first two payloads to the Gateway will be a radiation instrument package and a space weather instrument suite. (Artemis Plan, 2020) As the Artemis program is in the works, it is worrying that the solution to this problem has not been found yet.

The Sun is constantly emitting radiation, but some situations where the Sun emits solar energetic particles are far more dangerous. These particles can be emitted through flares or coronal mass ejections. Currently, NASA is prioritizing the prediction and understanding of such events to help protect astronauts outside of the Van Allen Belt. The current technique to protect yourself is by putting more mass between you and the SEPs. The problem is, in transit or in orbit, the astronauts only have what is on the shuttle. This leads to scenarios practiced on the Orion spacecraft, where the astronauts must barricade themselves in the center and put as much gear as they can around them.

There are some other options in development, like the use of electronically charged surfaces, in the hopes of deflecting the particles.

Though the Sun's radiation is a high priority, the astronauts will also have to worry about other radiation sources: galactic cosmic rays that are traveling almost at the speed of light caused by events like supernovas. These rays are constantly occurring, though sparse, are far more energetic, allowing them to penetrate deeper. This leads to a direct correlation to how long astronauts can be out in space before this constant radiation causes damage. (Tran, 2019)

Depending on the radiation, I am worried that this will be like the Fukushima situation. The radiation was too high for humans. To mitigate this issue, they created special robots to enter the dangerous area. Unfortunately, not even robots can handle certain radiation. With that, there was a mission where NASA launched a probe into the Van Allen belt. This mission was only supposed to be for 2 years, but the probes survived for over 7 years. As it seems, NASA will be using the Moon as a test to see the effects of the radiation and try to learn how to mitigate it. This leads to more worry about the long-term effects of the astronauts' health who would be exposed in the process, and the health of those later embarking on a far longer trip to Mars.

Helium-3

In the United States Space Policy, the United States stated a goal to establish and maintain a presence on the moon and utilize space resources. Along with the current energy crisis and humanity's presence on the Moon, mining for Helium-3 will help achieve said goal. With the abundance of the He_3 on the Moon, it could power Earth for 10,000 years through a nuclear fusion reactor. (What is Helium-3 and why is it so important?, 1999) Fusing atoms together releases nearly four million times more energy than a traditional chemical reaction, such as burning fossil fuels while not producing harmful by-products like CO_2 or radioactive waste. (ITER, 2022)

Helium-3, unlike the traditional helium molecule that has two protons, neutrons, and electrons, has only one neutron. Its existence was first proposed by the nuclear physicist Mark

Oliphant in 1934 and was originally thought to be radioactive. It was not until it was found in a sample of helium taken in the terrestrial atmosphere that it became known as the only stable isotope with more protons than neutrons. Due to the stability of this element, it is hypothesized to be perfect for nuclear fusion research. An issue is that it is incredibly rare on Earth but "naturally" occurs on the Moon. (What is Helium-3 and why is it so important?, 1999)

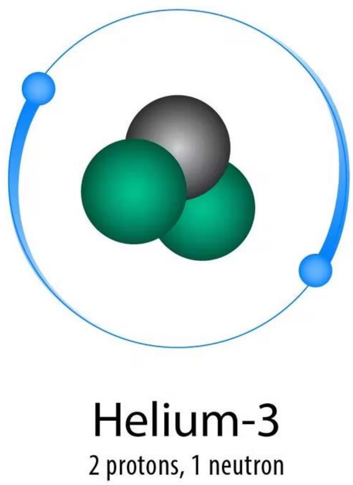

Figure 13: Helium-3

Source: “Machine Design.” (2018)

Retreived from https://www.machinedesign.com/materials/article/21836869/researchers-devise-a-longsought-workaround-to-helium3-shortage

Helium-3 only accounts for approximately 0.00001% of the helium on Earth. This last bit of evidence from nuclear fusion from ancient stars was trapped in small pockets on Earth while almost all of it escaped Earth’s atmosphere. This makes what we have left on Earth almost negligible. (Johnston, 2019) With the energy capabilities of Helium-3, it was stated during a hearing before the subcommittee on Science, Technology, and Space and the senate that one ton of Helium-3 would cost about $4 billion when compared to other forms of energy. (Schmitt D. , 2003) Unlike Earth, which has its own magnetic field for protection, the Moon has been receiving Helium-3 particles through solar winds for billions of years. Over time, this resulted in roughly 1,100,000 metric tons of Helium-3 being absorbed and left on the lunar surface. (What is Helium-3 and why is it so important?, 1999)

Fusion Reactor

The nuclear power plants we have today use the nuclear reaction fission. This produces heat, which then turns water into steam that drives energy turbines to produce electricity. To get this reaction, current fission reactors split uranium. Nuclear fission occurs when a larger isotope is split by bombarding the larger isotope with a smaller one like a neutron. The collision of these two particles results in fission. This type of reaction can also be seen in atomic bombs.

A fusion reaction is the opposite of fission. Instead of splitting atoms, fission takes place when two low-mass isotopes join under extreme pressure and temperature. This is the type of reaction that powers the stars in space and was used in the hydrogen bomb. The comparison of the atomic bomb and hydrogen bomb shows the energy production difference of these reactions. A hydrogen bomb was roughly 1,000 times more powerful and required an atomic bomb inside of it to produce the activation energy needed to start the fusion process to detonate the hydrogen bomb. (Chan, 2017)

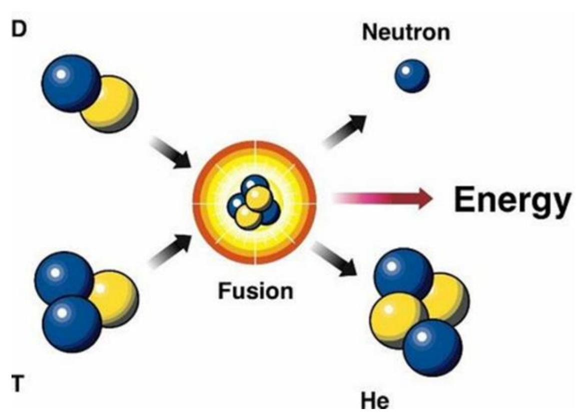

Figure 14: Fusion Reaction

Source: "Duke Energy" (2021)

Retreived from https://nuclear.duke-energy.com/2021/05/27/fission-vs-fusion-whats-the-difference-6843001

Currently, we mainly used fission reactors due to the fusion reaction being uncontrollable with our current technology. The issue with fission reactions is that they are radioactive and produce harsh waste that needs to be safely stored indefinitely. Unlike fission, a fusion reactor does not produce by-products during its reaction. This also removes the risk of a possible meltdown like Fukushima, or the inhuman use of the material in warheads. (ITER, 2022) Also, during a fusion reaction, energy several times the amount produced by fission is released. (Fission vs. Fusion - What's the Difference, 2021) For these reasons, it is apparent to pursue the technology of fusion over fission.

Today, there are fusion reactors in progress, such as an inertial confinement fusion from the National Ignition Facility and a magnetic confinement fusion called ITER, but neither expects to generate commercially generated power before 2050. Inertial confinement creates fusion by heating a micro sized target that is filled with thermonuclear fuel, creating the heat and pressure needed, while magnetic confinement utilizes magnetics to pressurize and heat the fuel. The magnetic confinement method is the most developed and promising of the two methods. (Prager, 2020) In both cases, they utilize hydrogen isotopes, Deuterium-Tritium fusion. "The reason for this is the very low Coulomb barrier for this reaction; for D+3He, the barrier is much higher, and it is even higher for 3He–3He." (What is Helium-3 and why is it so important?, 1999) Though the utilization of tritium is easier, tritium is a radioactive isotope, which is what we are hoping to not utilize when going from fission to fusion. Fission is also the most reliable source of tritium, defeating the purpose even more when utilizing tritium instead of He_3. (Baramsai, benyo, Forsley, & Steinetz, 2022)

FISSION REACTION OF URANIUM 235 BOMBRADED BY NEUTRONS:

$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\ {}^{1}_{0}n $$

FUSION REACTION OF TWO HELIUM-3 ATOMS:

$$ {}^{3}_{2}He + {}^{3}_{2}He \dashrightarrow {}^{4}_{2}He + 2\,{}^{1}_{1}p + 12.86\ MeV $$ or

$$ {}^{2}_{2}He + {}^{3}_{2}He \dashrightarrow {}^{4}_{2}He + {}^{1}_{1}p + 18.3\ MeV $$

FUSION OF DEUTERIUM AND H-3:

$$ D({}^{2}_{1}H) + {}^{3}_{2}He \dashrightarrow {}^{4}_{2}He + {}^{1}_{1}p + 18.4\ MeV $$

Figure 15: Fission VS Fusion Equations

Source: "EDinformatics." (1999)

Retreived from https://www.edinformatics.com/math_science/what-is-helium-3.html

Issues

The main issue holding science back with fusion reactors is that the fuel for these reactions needs to be heated to 100 million degrees Celsius or more, which requires an immense amount of energy input. Due to our technological limitations, we do not receive the same energy output, making it a loss of energy. Since the amount of energy needed to maintain those temperatures is so high, the current record for the lifetime of plasma at that level is less than 2 minutes. (Lemonick, 2021)

Another issue that companies are encountering with their systems is the lack of commercially obtained materials. Due to the cutting edge of this technology, supply chains of the chosen materials are not fully developed, making it hard to acquire such materials. Though this is an issue, the inventions and innovations discovered by overcoming these obstacles bring forth new technologies, such as flawless lenses and new materials. (Lemonick, 2021)

Record

Though fusion technology is still too far behind to solve the energy crisis just yet, each innovation is a positive step in the right direction of fusion. Recently, in August 2021, the National Ignition Facility (NIF) used 192 lasers aimed at a 2mm wide sphere made of a lab grown diamond containing deuterium and tritium for inertial confinement fusion. It takes about one week to grow the diamond, but two months to properly polish it to the correct dimensions. The lasers are sent through over 35,000 lenses to increase their power over one million billion times. This set up was able to create the hot, dense plasma at 100 million degrees Celsius and 1,000 g/cm^3, fusing deuterium and tritium, releasing 1.3 MJ of energy. Though, energy wise, this amount released would only be able to light a 60 W lightbulb found in everyday houses for only 6 hours. The technological leap was that this reaction released about 70% of the energy that was put in, closing the gap to create a positive, or net power. Steven Cowley, a fusion researcher at Princeton, stated, "From a scientific point of view, the NIF 1.3 MJ show was a monumental triumph. From an engineering point of view, inertial fusion is still a long way from energy breakeven." (Lemonick, 2021)

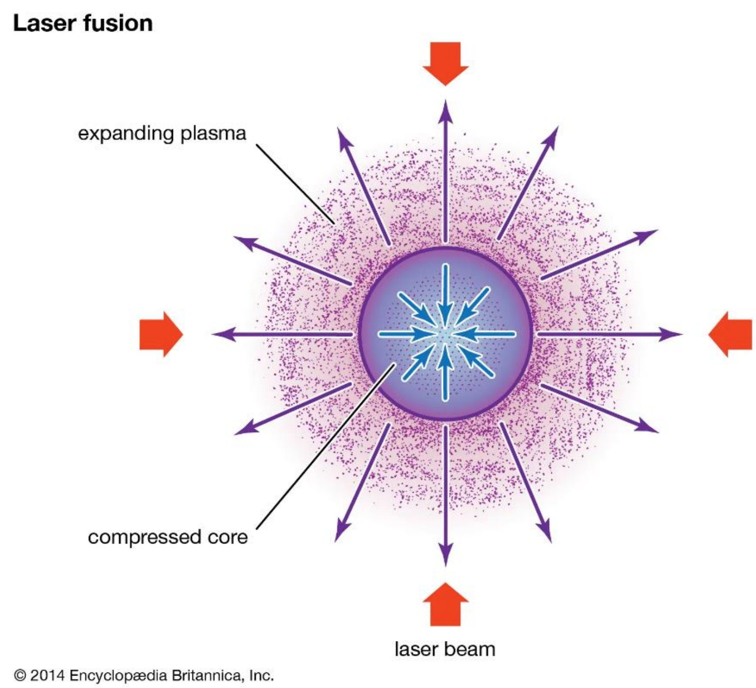

Figure 16: Inertial Confinement Fusion

Source: “Britannica” (2020)

Retreived from https://www.britannica.com/technology/fusion-reactor

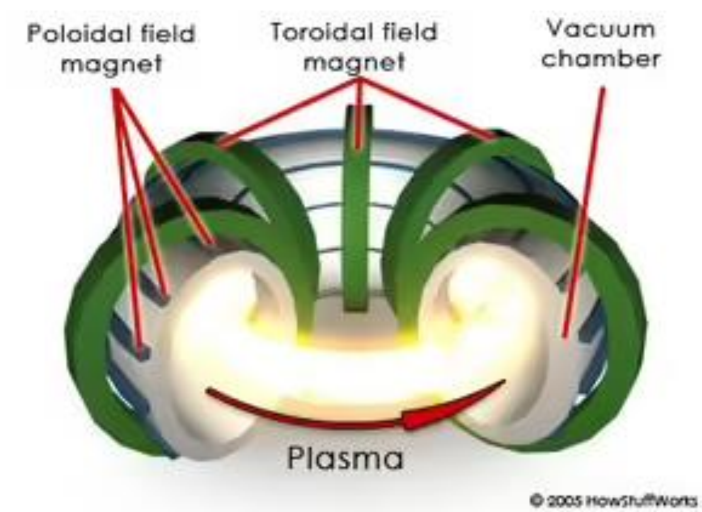

Figure 17: Magnetic Confinement Fusion

Source: “How Stuff Works” (2021)

Retreived from https://science.howstuffworks.com/fusion-reactor3.htm

Groundbreaking

Unlike traditional magnetic confinement fusion reactors that utilize two-ion fuels, MIT experimented with a three-ion fuel containing helium-3, deuterium, and hydrogen. This new fuel combination resulted in raising the energy released to megelectronvolt (MeV) levels. Due to this finding, MIT was funded to create Commonwealth Fusion Systems (CFS). CFS is utilizing an AlcatorC-Mod tokamak machine for magnetic confinement fusion reactors. The tokamak utilizes a doughnut-shaped chamber lined with magnetics to contain and compress the plasma to trigger fusion. CFS is constantly working with new materials to see what variables affect these reactions. Some of the innovations include a magnet using high-temperature superconducting barium copper oxide (REBCO) to produce a 20-tesla magnetic field and an internal blanket, the liquid that absorbs heat from the fusion reaction and drives the generator that will make electricity, made from a molten salt of lithium fluoride and beryllium fluoride (FLiBe). The advantage of FLiBe is that the neutron radiation from the reaction results in tritium being produced by the lithium, creating more fuel for the reactor. (Lemonick, 2021) With each advancement and invention, fusion reactors become more powerful, compact, and cost-effective to build and maintain, bringing them closer to being a viable solution to the energy crisis.

Utilizing the new innovations and materials presented above, MIT and CFS are in the process of building SPARC. SPARC is claimed to be the "world's first fusion device that produces plasmas which generate more energy than they consume, becoming the first net-energy fusion machine." (SPARC, 2022) This device's production is currently in construction, with plans to create a fusion power plant for commercialization starting in 2025.

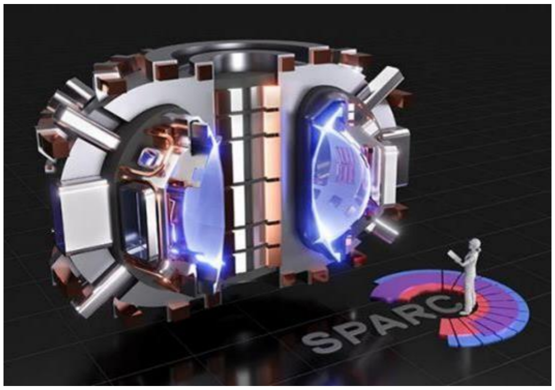

Figure 18: SPARC

Source: "CFS energy" Retreived from https://cfs.energy/technology/#hts-magnets-enabling-technology

Also planned for 2025, ITER is a multi-nation collaboration of 35 nations to build the world's largest tokamak, which uses magnetic confinement fusion as well. This device is also planned to be the first fusion reactor to produce net energy. The tokamak will take advantage of the scale of the vessel to contain a 10x larger volume of plasma, allowing for greater fusion energy. The current record for fusion power ratio produced is 16 MW from a total of 24 MW. ITER is designed to produce 500 MW of fusion power from only 50 MW of input power. (ITER, 2022) This is not only a positive step in fusion capabilities, but also a step in the direction of being able to utilize lunar resources to help all humankind on Earth. With net power capabilities, it is less of a stretch to pursue these types of energy sources.

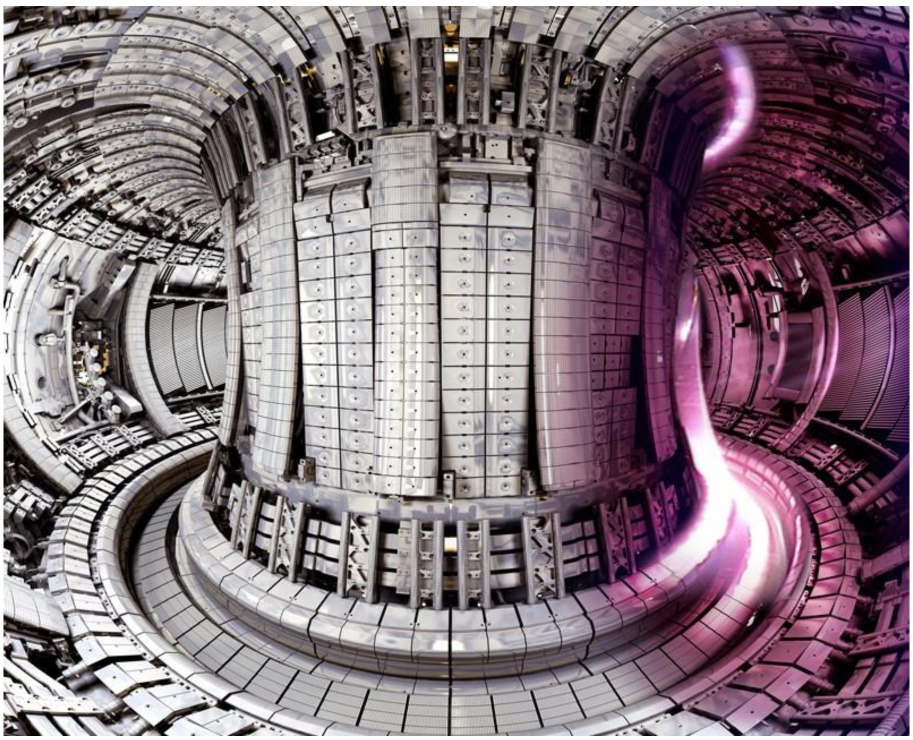

Figure 19: Inside ITER

Source: "Nature" (2021)

Retreived from https://www.nature.com/articles/d41586-021-00408-1

Lattice Confinement Reaction (LCR)

Both magnetic and inertial confinement reactors require an immense amount of power, one for massive super magnets which need to be super-cooled or powerful lasers. Both cases also need bulky, complex, and expensive machines. During research on how to power deep-space probes, NASA may have discovered a simple, compact, and more efficient method to perform fusion. This theory is called the Lattice Confinement Reaction (LCR). (Baramsai, benyo, Forsley, & Steinetz, 2022)

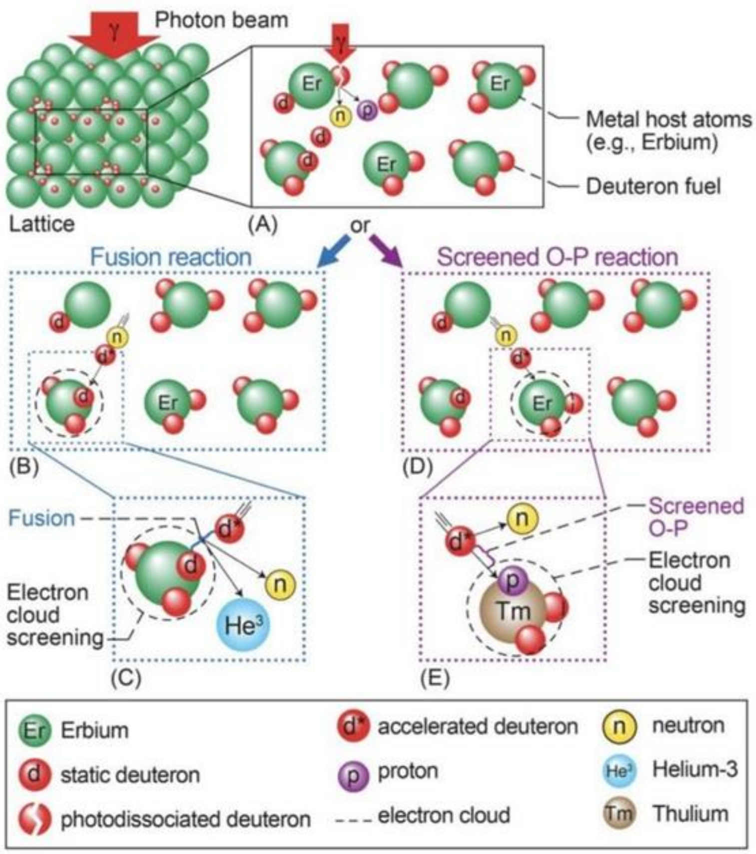

Figure 20: Lattice Confinement Reaction

Source: "Medium" (2022)

Retreived from https://medium.com/predict/has-nasa-cracked-fusion-energy-1eb79fb55178

LCR uses a metallic lattice of erbium saturated with deuterium to efficiently get the hydrogen atoms dense enough to fuse. The hydrogen atoms occupy the spaces between the metal atoms, with the massive density obtained due to the metallic bonds pushing the hydrogen atoms together, forming a material called deuterated erbium. To get the last bit of energy needed to increase the pressure on the atoms for fusion, gamma-rays are shot at the deuterated erbium, hitting some of the hydrogen atoms directly, causing them to become energized and bounce around the material, hitting other hydrogen atoms, resulting in fusion. The by-product of this method will either be a helium-3 nucleus with a left-over neutron or a hydrogen-3 nucleus with a leftover proton. These fusion products may combine with other deuterons to form an alpha particle, or with another helium-3 or hydrogen-3 nucleus, releasing more energy, which helps to fuel additional fusion reactions. (Baramsai, benyo, Forsley, & Steinetz, 2022)

If NASA can perfect this method of fusion with the collection of the outputted energy, it will be revolutionary. This will not only benefit the space industry by powering space shuttles and robots on the moon or Mars but can power Earth as well. Due to its simplicity, its cost will be low to manufacture, while still providing an immense amount of clean energy.

Helium-3 Race

With LCR still in early development and completed in only small-scale experiments, it is unlikely that it will be the first commercial fusion reactor. In my opinion, magnetic confinement fusion reactors have the opportunity to be the first, especially with ITER and SPARC in production, which are planned to produce net energy or more within the next few years. With helium-3 being on the rise as a key element for the fuel for fusion along with other uses, we are currently running out of our small supply of it on Earth. Due to this fact, Charles Ferguson, the president of the Federation of American Scientists, stated that the shortage of helium-3 has created a "huge national security problem". (Caroll, 2021)

Whoever controls the helium-3 market, controls the next energy supply for the world. The only two options to claim more helium-3 are to increase production of tritium through fission or to expand our reach to the Moon. For the reasons stated above, mining the moon is our only viable option. China has already been mapping out the Moon for helium-3 fields, and if they gain control over it, they will monopolize the market. At our current understanding of $140 million per 220 lbs., and the Moon has about 1.1 million tons of helium-3, the value of helium-3 on the Moon is $1.5 quadrillion. (Schmitt H. H.) This issue makes it imperative that the United

States and its allies get there first, where they have already stated their policies on fair resource trading in the Space Policy.

Lunar Base Location

As we set forth plans to visit the moon and then colonize it if possible, a lot of research and planning is going into choosing an appropriate location for a lunar base. Picking the correct location considers a lot of variables that dictate the viability of the spot, such as resources, sun, and geography of the area. Having the ability to be self-sustaining from the lunar surface itself is mission critical as it will make a lunar colony a viable option as a staging ground for future and farther exploration into deep space.

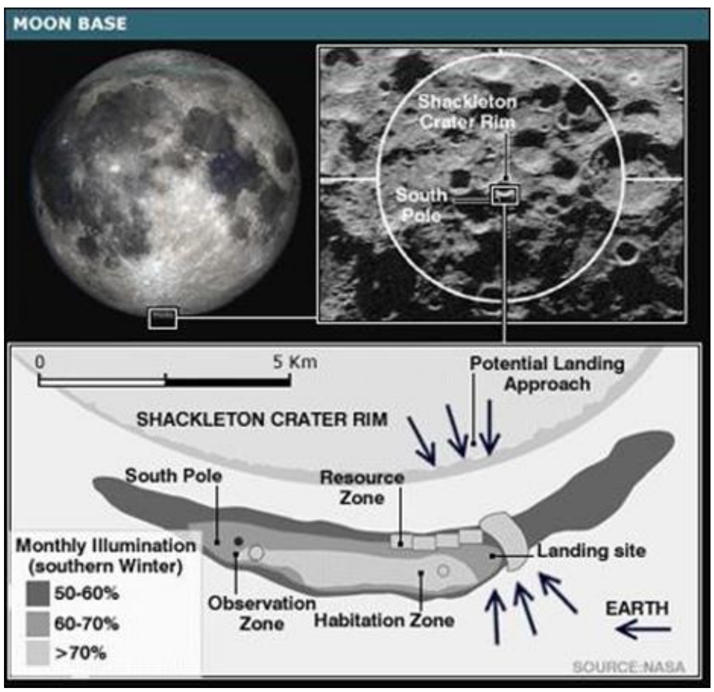

Figure 21: Shackleton Crater for Home Base

Source: "Leonard David's INSIDE OUTER SPACE" (2019)

Retreived from https://www.leonarddavid.com/moon-boots-making-tracks-to-shackleton-crater/

One of the most important assets for maintaining a lunar base and colony would be power. Currently, that source of power will be the sun. The Earth has a 23.5-degree tilt on its axis, which causes longer days in the summer and less sunlight in the winter. The Moon, on the other hand, only has a 1.5-degree tilt, causing the poles to have a consistent amount of sunlight. (Rayne, 2021) To make sure the base and outpost get an efficient amount of power; the North and South Poles are ideal locations. Elevation also increases the amount of sunlight received, narrowing areas in the poles even more. This results in the craters' mouths being the areas that receive the most light possible on the Moon. Areas such as Shackleton Crater receive sunlight for an average of 200 Earth days a year. (Dunbar, 2019) Due to the need for sunlight, higher elevations in the moon's North and South poles are ideal locations.

During our lunar operation, resources such as water will be mission critical. Water will be needed for the astronauts to survive and maintain hygiene. The water molecules also have the potential to be split by electrolysis to provide oxygen for breathing and hydrogen for fuel for the rockets. Though water could be transported to and from the Gateway and then to the lunar surface in emergencies, a more viable option would be for the outpost and bases to be self-sustaining from the lunar surface.

NASA’s Stratospheric Observatory for Infrared Astronomy (SOFIA) was dispatched to try and detect water on the Moon. SOFIA is a modified Boeing 747SP jetliner with a 106-inch diameter telescope using infrared cameras to detect specific wavelengths unique to water. SOFIA was able to confirm water all over the Moon. NASA plans to use the data collected by SOFIA and VIPER, the lunar resource detecting rover, to create the first ever water resource map of the Moon to aid future exploration. Although SOFIA was able to detect water in areas touched by sunlight, they are not the most practical option for water. According to the data, most areas touched by sunlight had over 100 times less water than what can be found in the Sahara Desert. (Rutter, 2020)

To have easier and more access to water on the lunar surface, we need to look where the sun does not reach. Due to the tilt of the Moon that allows some areas to have constant sunlight, this low-grade tilt allows for some areas to be stuck in complete darkness, specifically at the poles. In these permanently dark craters, the temperatures are as low as -414 degrees Fahrenheit. (Dunbar, 2019) Here, astronauts will be able to find frozen water they can utilize.

To narrow the location even more, the Lunar Orbiter Laser Altimeter (LOLA) was able to analyze the poles of the Moon with great precision. Using the data LOLA gathered, scientists were able to confirm that the southern pole contained far more frozen water than the northern pole. (Li, 2018) This can be seen in the provided Figure 22.

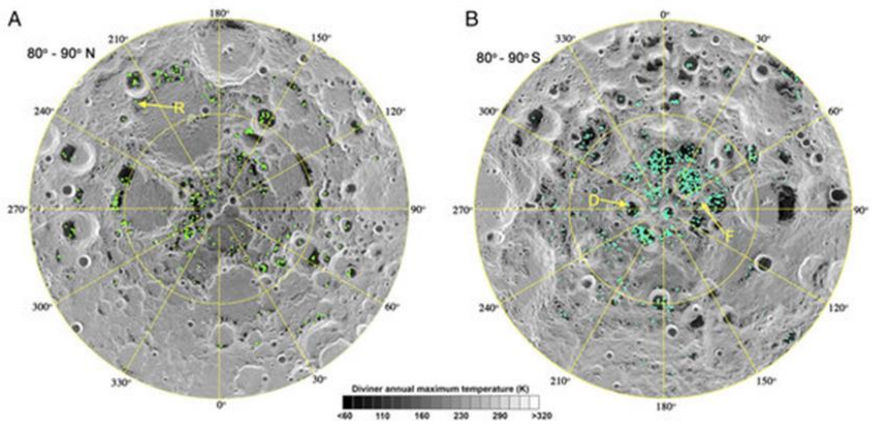

Figure 22: Confirmed Ice on Poles

Source: “PNAS” (2018)

Retreived from https://www.pnas.org/doi/10.1073/pnas.1802345115

With eyes now focused on the southern pole, specifically near large craters like the Shackleton Crater, we can analyze the geography of the Moon and analyze communication capabilities to narrow down a location between the far side and the nearside of the Moon. Originally, communication would have been a major issue to maintain contact on the far side of the Moon. During the original Apollo missions, when astronauts were behind the Moon, we would lose contact with them due to interference. In modern times, the use of relay satellites in the L2 LaGrange point on the far side of the moon is being utilized. This method can be seen being used with China’s Chang’e-4 lunar rover as its area of operation is the Von Kármán crater on the far side of the southern pole. (Collins, 2020) Though communication is capable on the far side, if there was an issue with the relay satellite, it would lead to communication failing.

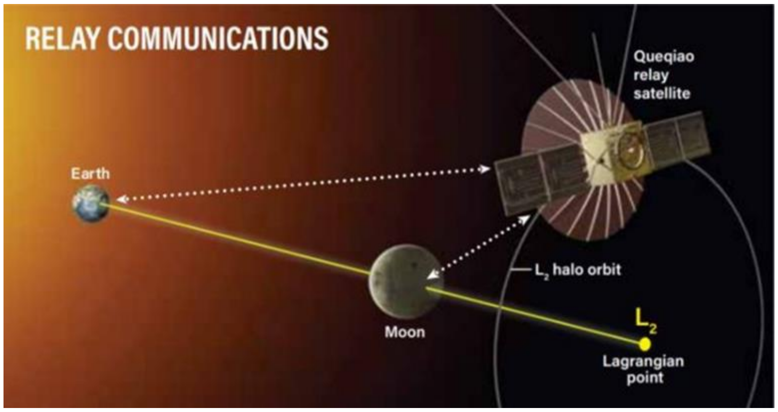

Figure 23: Relay Satellite

Source: "Astronomy" (2020)

Retreived from https://astronomy.com/magazine/ask-astro/2020/09/how-do-spacecraft-communicate-from-the-farside-of-the-moon

There are a few things we need to look for to make sure the geography is accessible. To start, there needs to be flat terrain for landing zones, while also using the terrain to block any flying debris from the landing to protect the outpost. Using maps generated by the Lunar Reconnaissance Orbiter (LRO) the far side of the Moon is far more clustered with craters. Though this would be good for cover or the crater mouths for sunlight, this would make it harder to find flatter terrain for landers and harder to maneuver rovers or other land vehicles. (Davis, 2019) With this issue and possible emergencies with communication, the near side is preferable.

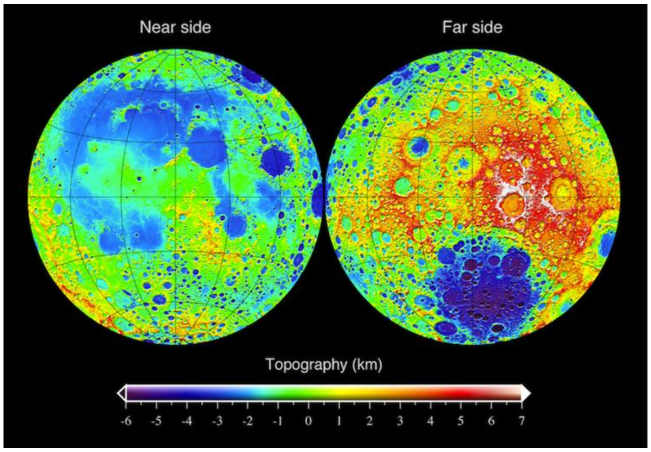

Figure 24: Topography of the Moon's Sides

Source: "Lunar and Planetary Institute" (2019)

Retreived from https://www.lpi.usra.edu/lunar/missions/clementine/images/

To summarize, the ideal location and the variables considered: First, to make sure we get enough sun to power the base and electronics, being near a crater mouth on one of the poles is preferred, as they receive the most sun due to the elevation and the Moons tilt. Being near a crater also gives access to water. To make sure water is more accessible and available, the southern pole is preferred due to the data gathered by LOLA. Finally, to narrow down the location even more, emergency communication and the smoother geography of the near side result in the near side of the Moon being preferable to the far side. Overall, the ideal situation for initial location is near a crater at the southern pole on the near side of the Moon.

Artemis III is planning on sending astronauts to the lunar surface. NASA is currently focusing on the mobility of the mission, allowing them to branch out and explore and discover possible resources for the future. Though they plan to be mobile, an initial location and area are still important. NASA has set an initial location to be the southern pole near the Shackleton Crater. (Artemis Plan, 2020) This follows suit with all the variables discussed above. Being located on the near side of the Moon still allows the astronauts to gather new data on the mysterious far side, as it is right there as well, while also exploring to find more suitable locations for permanent colonies.

This location works perfectly with the current considerations of an initial location for a lunar presence. For lunar permanence in the upcoming years, these variables may change, allowing for different areas to be better than others. Some variables that may change or be added, such as the protection from micrometeorite and radiation and the change in the need for sunlight for power.

Micrometeorite impacts and protection from radiation are always an important issue when it comes to space travel. The high mobility of the Artemis III mission results in the need for less permanent solutions. This leaves the habitable mobility platform (pressurized rover) and the foundation surface habitat module to provide protection for these issues. (Artemis Plan, 2020) These will provide adequate protection for the short-term missions, but for lunar permanence we will need more permanent solutions. A strong possibility for a lunar colony would be an underground base. This can be accommodated by building a base under regolith or even utilizing the natural lava tubes or caves on the Moon. Having an underground base would provide the most protection from these micrometeorites and cosmic galactic radiation.

Along with protection from impacts and radiation, a recent study from the University of Colorado Boulder stated that temperature conditions are far more stable underground than on the surface. As it has been discussed, the temperature of the surface of the Moon fluctuates heavily between day and night, hovering around 250 degrees Fahrenheit during the day and dropping to below -208 degrees Fahrenheit during the night. In most of the simulated lava tubes the researchers modeled, the temperature stayed between 94- and 184-degrees Fahrenheit. (Williams, 2022) This stability would allow for easier maintenance of a habitable temperature. Though this would make the ability to gather water from said tubes unlikely, there is the possibility of some tubes providing access to deeper trapped frozen water in certain geographic locations.

Utilizing lava tubes as possible colony locations also results in operating on the near side of the Moon. It is uncertain exactly why, but the near side of the Moon was far more volcanically active than the far side. A possible theory is that "while the Earth and Moon were forming, heat from the still-molten Earth slowed the cooling process of the near side of the Moon. The far side could solidify faster, forming a thicker crust." (Davis, 2019) This allowed the near side to stay more volcanically active longer. The thicker crust also resulted in impacts causing less opening to the lave tubes as well. On the near side, a meteorite impact would puncture the crust, resulting in easy access to these tubes, while the thicker crust would protect these tubes from impacts.

Currently, the need for sunlight to power these colonies is the only solution. If these colonies were embedded in caves, tubes, or underground, this would result in long power lines to connect to solar panels on the surface. A possible future solution would be to utilize a fusion reactor to power these colonies. A valuable resource on the Moon is helium 3, which would be a key ingredient in fusion reactors. This allows for a self-sustaining colony that would be able to mine resources like helium-3 and water from the surface and then transport them to the colony.

Advantages of the Moon

NASA’s Artemis program is set to have an outpost on the Moon by 2028, which will be the initial step towards a permanent presence on the Moon. Colonizing the Moon is not just an exploration and space travel dream; it also brings forth strong advantages that will be necessary for humanity to thrive. We spoke previously of helium-3 being mined on the Moon, but there are far more volatiles that can be mined as well to make the colonies self-sustaining and profitable for humanity on Earth such as water or rare Earth metals. With resource mining, post-processing these materials in a vacuum and low gravity has some advantages as well. With the ability to mine certain resources, astronauts can utilize them and the low gravity to increase the efficiency of launches, making them a perfect jumping point for future exploration into deep space. Another advantage of colonizing the Moon is that, due to the way the Moon's rotation occurs, humanity can take advantage of the near-side and far-side orientations for uses like overwatching the Earth and radio telescopes. Finally, using the Moon for planetary defense can be a crucial element for humanity's survivability.

Mining

Not only does the Moon contain helium-3 and water, but it also holds various elements such as rare earth metals. Being able to mine some of these elements from the Moon takes some stress off the Earth. It will allow for less pollution to occur on Earth while taking advantage of the lack of atmosphere on the Moon to disperse any of the harmful by-products. While some of the more common elements like iron, quartz, and silicon can be utilized for more common applications like buildings, there are accounts of 17 rare metals that are scarce on Earth that are able to be found on the Moon that can be used to produce things such as engines and electronics. (Staedter, 2020)Through the Lunar Reconnaissance Orbiter (LRO), some elements, such as titanium, have been discovered to be 10 times more abundant than on Earth. (Soderman, n.d.) Once the titanium ore is processed and combined into an alloy with other common metals found on the Moon, it can be used in various applications such as construction material for buildings, or even parts for vehicles such as engines.

Post-Processing

Once these volatiles are mined and collected, there are some options for what to do with them. The material can be bundled up and sent back to Earth to be post-processed and used on Earth, or we can take advantage of some processing techniques that benefit from a lunar environment. Currently, we utilize vacuum in only certain fields such as semiconductors and micro-or nano-scaled processing. This is due to the high cost of large-scale vacuum-sealed locations to be used in larger applications. Post-processing metals in a vacuum poses a strong advantage due to the effects a vacuum has on the chemical and physical properties of the material. One of the first benefits can be seen in the reduced impurities in the metal compounds. A vacuum space also helps prevent oxidation, allowing for the processing of materials such as magnesium and titanium, which have high oxidation speeds. (Reitz, 2021)Other manufacturing methods benefit from vacuum as well; welding two joints in vacuum increases penetration depth, increasing the strength of the weld. Welding in low pressure or vacuum also increases the efficiency of CO_2 welding as it also suppresses the plasma. This comparison can be seen in Figure 25. (Jiang, Tao, & Chen, 2017) Being able to utilize the infinite vacuum of space will drastically cut the cost of trying to replicate a vacuum on Earth.

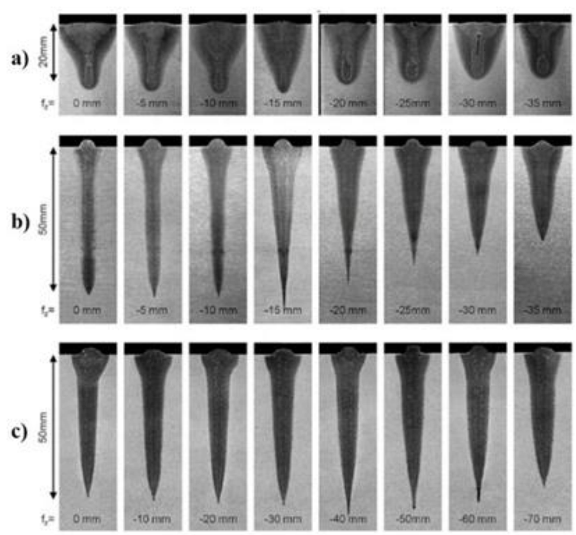

Figure 25: Welding Comparison

Comparison of cross section profiles using different welding processes (a) Laser welding (laser power is 16 kW, welding speed is 0.3 m/min, ambient pressure is 1000 mbar), (b) Laser welding under vacuum (laser power is 16 kW, welding speed is 0.3 m/min, ambient pressure is 10−1 mbar), (c) Electron beam welding (electron beam power is 16 kW, welding speed is 0.3 m/min, ambient pressure is 10−3 mbar).

Source: “MDPI” (2017) Retreived from https://www.mdpi.com/2076-3417/7/9/909/htm

Not only does vacuum help in post-processing and manufacturing, micro-gravity also shows advantages. Lynn Harper, the lead of integrative studies for the Space Portal partnerships office at NASA's Ames Research Center in California, states we need newer technology that will help mitigate defects at atomic- and molecular-levels. Microgravity manufacturing reduces defects and contaminations by allowing for even expansion while avoiding enclosure walls. Some innovations and inventions benefiting from micro-gravity can be seen in a special fiber optic called ZBLAN. This thin cable, when produced in micro-gravity, is less susceptible to developing small imperfections. (Lewin, 2018) Also, a new form of post-processing metal, called foaming metal, which involves injecting molten metal with gases, will benefit from the even distribution of bubbles. Instead of the bubbles trying to rise during the slow annealing process, they will stay more distributed. Foaming metal results in the material becoming ultralight due to the high porosity while maintaining a strong strength and increases in compression and energy absorption characteristics. The application for this material can be used in structures or vehicles to cut down on weight and increase safety on impacts. (Thomas, 2013)

Efficiency for Space Travel

By taking advantage of the micro-gravity and vacuum and the ability to mine and process the materials, the Moon becomes a perfect jumping point for further deep space exploration. Because the gravitational force on the lunar surface is roughly one-sixth that of the Earth's, the amount of fuel required to lift a vehicle off the Moon would be substantially lower than the amount needed to launch it from the Earth. With this increase in efficiency, we can increase the payload amount, such as fuel and water, to allow for farther travel than we can currently accomplish by deploying from Earth. (Miyano, 2018) A study on the Delta-V, change in velocity between each trajectory or "checkpoint" of travel, shows how much more efficient a lunar takeoff to Mars is than from Earth. As seen in Figure 26, it takes a Delta-V of 10 km/s to just reach Low Earth Orbit (LEO), and a sum of 9.3 km/s to reach Mars from the Moon. Also, the ability to mine water from the Moon allows for the ability to split it into oxygen and hydrogen, creating rocket fuel, drastically reducing the cost of deep space travel. These combined advantages will become necessary if we intend to expand the humanities' reach.

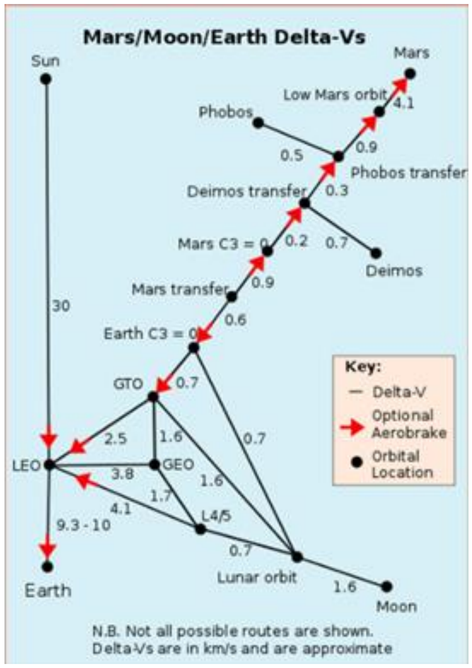

Figure 26: Delta-Vs

Source: “Wikipedia”

Retreived from https://en.wikipedia.org/wiki/Delta-v_budget

Tidal Locking Advatages

Due to the Earth’s gravitational pull on the Moon, it has slowed the Moon’s rotation, creating the phenomenon known as tidal locking, where the orbit and rotation of the Moon match. This causes only one side of the Moon to be visible to Earth, while the far side always remains outward facing. Against popular belief of calling the far side the dark side of the Moon, both sides receive an equal amount of sunlight. Humanity can take advantage of the constant orientation of the Moon around Earth for various applications. The near side of the Moon can be utilized for applications such as an overwatch of Earth, or a preferred location for a base due to its ability to receive constant communication. The far side of the Moon is perfect to equip with a radio telescope or similar.

Radio Telescope

Utilizing the far side of the Moon with a radio telescope has some strong advantages over being on Earth. Earth's ionosphere blocks the telescopes from seeing longer wavelengths over 33 feet and under one centimeter. Even the wavelengths that do make it through receive small amounts of distortions, making it necessary to be processed by software to correct the data. Due to the Moon not having an atmosphere, this issue would be solved. NASA stated that "access to longer radio wavelengths will be particularly effective for probing the universe's Dark Ages". (Whitt, 2021) This will allow for earlier object detection of asteroids that might pose a risk to Earth. The use of the far side of the Moon also presents another advantage. The Moon itself will be blocking any Earth-emitted radio chatter, allowing for less disruption or noise.

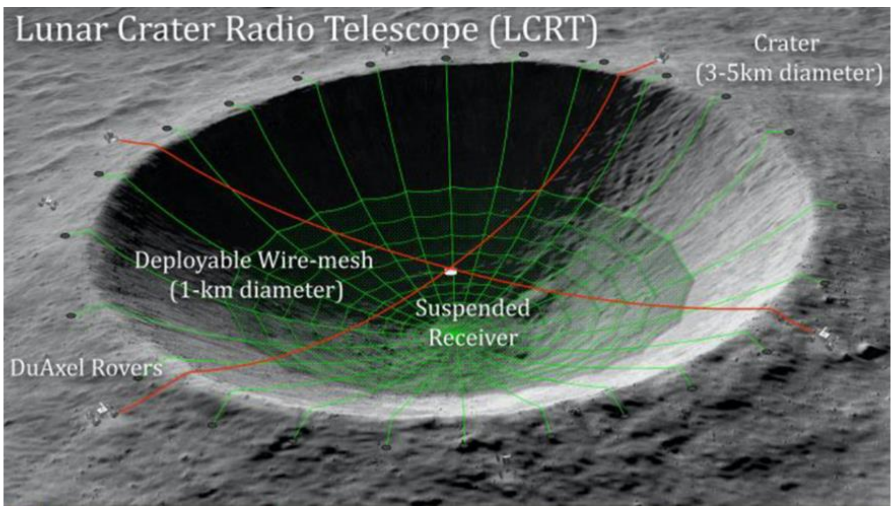

Figure 27: Lunar Crater Radio Telescope

Source: "EarthSky" (2021)

Retreived from https://earthsky.org/space/lunar-crater-radio-telescope-lcrt-phase-2-duaxel-radio-waves-dark-ages/

Due to these advantages, NASA awarded the Lunar Crater Radio Telescope (LCRT) $500,000 to continue their research and development. This project will take advantage of the Moon's geography and utilize a pre-made crater to form the shell of the telescope. Using the accomplishment of China's Chang'e 4, the only spacecraft to successfully soft-land on the Moon, this program will use a multi-landing system. Each robotic system will be landed in and around the crater to help unfold and deploy the material needed. The robotic rover concept they are planning to use is the DuAxel, a dual rover system connected together by a tether. One of the rovers will anchor at the top while the other repels down the crater's wall to meet the lander that landed inside the crater. This lander will deploy a wire mesh and receiver that the DuAxel will attach to and unfold as it retracts its tether back to the anchored rover. This type of system would drastically cut costs as a giant shell would not be needed to be built. As we colonize the Moon as well, these systems can be launched from our outpost to the far side, drastically cutting fuel costs. Or if the crater is close enough to an outpost, they can be built manually by humans or robots.

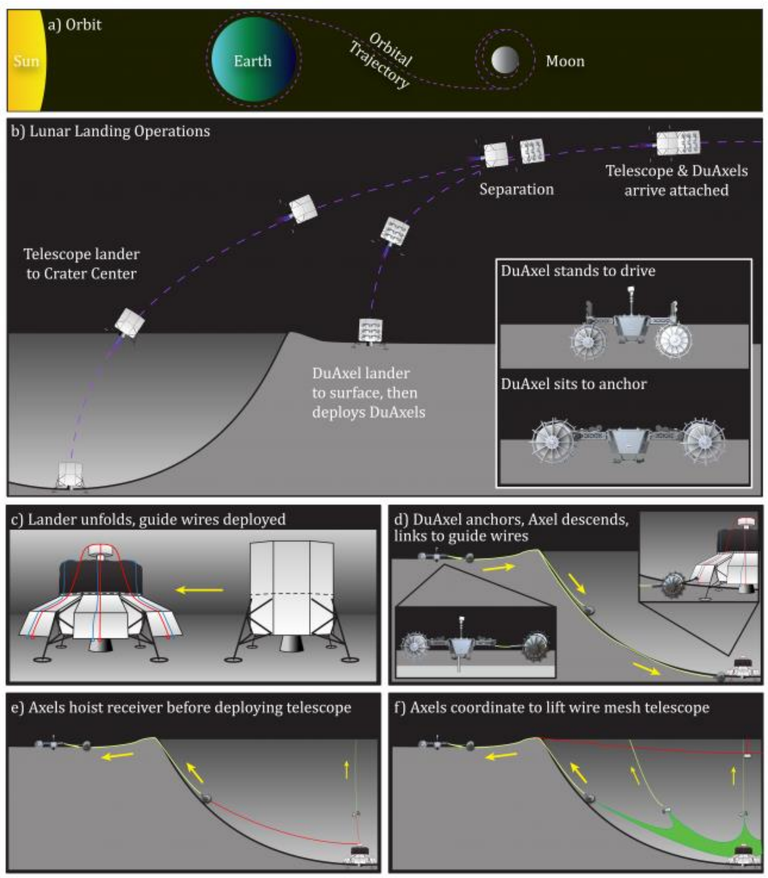

Figure 28: Lunar Crater Radio Telescope Deployment Concept

Source: "EarthSky" (2021)

Retreived from https://earthsky.org/space/lunar-crater-radio-telescope-lcrt-phase-2-duaxel-radio-waves-dark-ages/

Planetary Defense

Not only does the Moon provide a perfect opportunity to see farther into space, but it may also be the only chance we have to protect our planet from what it is hiding. The Moon is an ideal platform to launch interceptor missions to protect us from asteroids or other objects set to impact the Earth. With our current data, there are over 10 million asteroids with a diameter of 20 meters, which shows an indication of an impact every 50 to 200 years. The effects of smaller impacts can be seen in the impact in Chelyabinsk, Russia in 2013. This 20-meter asteroid caused a shockwave that injured 1,200 people. (Wall, 2013) Sometimes, a meteor does not even need to have a full impact on Earth to cause devastation. Near the Tunguska River in Russia in 1908, a 50-meter diameter asteroid shattered from entering Earth's atmosphere, causing an explosion equivalent of 185 Hiroshima bombs, causing eight hundred square miles of forest to be ripped apart. (Phillips, 2008) If an event like this occurred over a populated area, the results would be horrific.

The current method for intercepting smaller asteroids under one km is a kinetic interceptor. This just includes crashing a large space craft into an asteroid, either slowing it down enough to set it off course or destroying it. This can be seen in NASA's mission Double Asteroid Redirection Test (DART). This is NASA's first demonstration of a kinetic impactor. This mission sent the 19-meter kinetic impactor into space to impact Dimorphos, a smaller 163-meter moonlet asteroid, at 14,000 mph to disrupt the trajectory. (DART, 2022) It was launched in November 2021 and is scheduled to impact in late 2022.

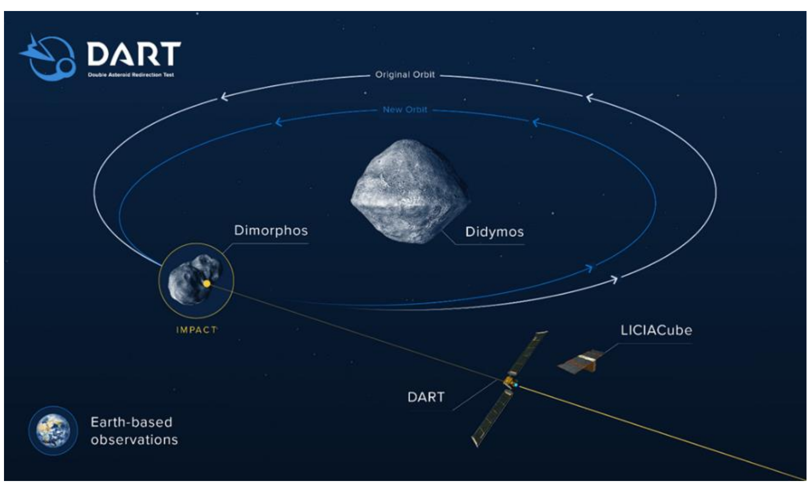

Figure 29: DART: Kinetic Impactor
Source: "Johns Hopkins applied Physics labratory" Retreived from https://dart.jhuapl.edu/Mission/Impactor-Spacecraft.php

As we stated earlier, the ability to launch from the Moon is far more efficient, allowing for more mass to be sent up into space. This will allow a kinetic impactor to be drastically more efficient than one sent from Earth. (Miyano, 2018) This added mass can even be the mined regolith from the Moon during mining operations, to make these interceptors more efficient than supplying the Moon with materials for these missions. According to NASA it would be too late to shoot down an asteroid even hours before impact, that the more time we have, the better off we will be. The use of the Moon will allow for a head start on intersecting a trajectory due to its increase reach compared to Earth.

Though rare, larger asteroid impacts have occurred over Earth's history. Of the known 190 impacts, over 44 were asteroids over 20 km in size. Gerhard Drolshagen, a physicist who specializes in near-Earth objects at the University of Oldenburg in Germany and the former director of the United Nations' Space Mission Planning Advisory Group, stated that an object over one kilometer impacting Earth would have global effects. (Coffey, 2022) With kinetic impactors not being effective with these sized asteroids, it results in a nuclear solution. This poses a problem as our current technology is incapable of sending a nuclear warhead large enough to combat a two-kilometer asteroid into space from Earth. This provides a strong advantage for a lunar launch platform as the only option to defend Earth from such impacts. The lunar surface can also provide the materials needed to make these nuclear weapons, as a Japanese spacecraft scan provided data to support the presence of uranium and thorium on the Moon. (Miyano, 2018)

The foreseen issue with utilizing the Moon for planetary defense with these methods, is that it goes against the 1967 Outer Space Treaty. This treaty prohibits the installation of military bases and weapons on the moon, but due to its strong advantage of being the only current option theoretically capable of stopping the impacts, benefiting all mankind, a workaround would be a must. Workarounds have occurred, as the 1967 Treaty stated that nothing in space was up for claims or occupation, but due to the rise in hopes of mining the Moon. The United States passed the Commercial Space Launch Competitive Act, which ensured US companies would have the right to claim anything they collect from space.

A concept in the work that would also act as a workaround would be the use of laser ablation on the asteroids. This method would use lasers to alter the orbit of an asteroid. It would accomplish this by heating the surface enough to cause gases to eject like a rocket engine, altering its trajectory enough to miss its impact on Earth. According to NASA, the use of this method can alter the trajectory enough for a one-kilometer-sized rock in about a month, while smaller objects can be moved in less. Utilizing the Moon for this method would be beneficial as it is stated that small-scale turbulence in the Earth's atmosphere requires adaptive lenses for the lasers, making it more accurate and less expensive to utilize the Moon instead. (Campell, Phipps, Smalley, Reilly, & Boccio, 2002)

Another avenue of approach for this method is that instead of utilizing massive lasers, a swarm of smaller spacecraft can be deployed from the Moon equipped with smaller lasers. The spacecraft would then be able to deploy the laser at different points instead of a direct shot from the Moon, allowing for more controlled thrust creation during the process. This theoretical but promising method, called "Laser Bees," is currently being worked on by small teams at the University of Strathclyde and the University of Glasgow in Scotland. (The Planetary Society, n.d.)

LASER BEES: ZAPPING OLIVINE ROCK WITH A LASER Laser Bees asteroid deflection project: zapping olivine rock with a laser, this shows the ablation response of the olivine on the left, with ejecta (pieces) coming out, and on the right with a mini "rocket plume".

Figure 30: Laser Ablation

Source: "The Planetary Society"

Retreived from https://www.planetary.org/sci-tech/laser-bees

These benefits of expanding our reach and colonizing the Moon show a promising future. Not only will it provide further vision into deep space or better processing of mined materials, but the Moon also possesses key elements for new energy, like utilizing helium-3 for fusion reactors. The Moon also provides an ideal location to expediate the capabilities of deep space travel and is currently the only option for a strong planetary defense.

Preservation of Humanity

Humanity's fate is uncertain. There are very real risks that could end our fragile race, such as astroids, solar flares, climate change, and even a nuclear armegedon. The Moon and other celestial bodies in space can provide a safe house in case of a genocidal event to preserve the seed of humanity. Not only will it allow the humans off Earth to survive an event, if it is an event like a nuclear war, the Moon can be used to wait out the radiation before recolonizing Earth.

In a worst-case scenario, the Moon could act as Noah’s ark for humanity and other earthly species. The Moon and other off-planet locations can be utilized to host a genetic resource bank, allowing the DNA of all known species to be stored and used at a later time if necessary. Utilizing space to spread humanity as far and wide as possible maybe be the only way to ensure the survival of our species.

Electromagnetic Propulsion

Although it is possible to create rocket fuel from resources on the Moon, it would be beneficial to utilize the water found for other life support needs, such as drinking and hygiene. As stated, the escape velocity on Earth is roughly 11.2 km/s, while on the Moon it is only 2.42 km/s. By taking advantage of the smaller escape velocity, there is an opportunity to minimize fuel acceleration by utilizing electromagnetic propulsion to act as an accelerator to send objects from the Moon into heliocentric orbit. An electro-magnetic accelerator utilizes magnetic propulsion to transport objects at high speeds. This technology is currently used on Earth in various departments, such as transportation and military use. An accelerator would have multiple uses, such as lunar transportation; deploying cargo to various points in orbit or Earth; an asteroid interceptor; and accelerating launch vehicles to mitigate the use of fuel.

Current on Earth

The United States Navy is utilizing this method in both defense and transportation aspects. One use currently is in an electromagnetic rail gun. This gun would launch a projectile with an exit speed of 2 to 3.5 km/s. The rail gun utilizes parallel conductors to act as rails to guide the armature. As seen in Figure 31, the force created is a Lorentz Force and can be determined by utilizing the equation $F = i \times L \times B$. Next, the Navy is currently using electromagnetic propulsion to assist aircraft launching off ships. The Electromagnetic Aircraft Launch System (EMALS) uses a linear induction motor that acts as a slingshot on the deck of the ship to accelerate the aircraft smoothly and rapidly to beyond the aircraft's stall speed. The EMALS can accelerate a 36-ton sled at 333 km/h. (Miyano, 2018)

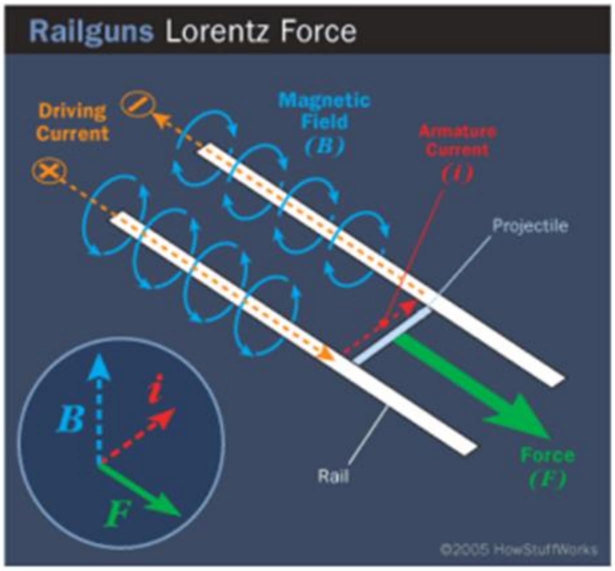

Figure 31: Lorentz Force

Source: "How Stuff Works" (2005

Retreived from https://science.howstuffworks.com/rail-gun1.htm

A famous use of electromagnetic propulsion is seen in Japan's Magnetic Levitation (MAGLEV) train. These trains weigh around 420 tons and can reach speeds of up to 603 km/h. The MAGLEV levitates about 100 mm above the ground, making it safer during possible earthquakes. These advantages will also be helpful on the Moon, as Apollo astronauts first discovered moonquakes that last up to an hour. (Miyano, 2018)

On Moon

The current issue with utilizing an electromagnetic acceleration system like this on Earth is to overcome aerodynamic heating and drag, but due to the Moon's lack of an atmosphere, this issue would be nonexistent. When converted, a system like the MAGLEV would only weigh about 1.6 tons and reach speeds of 2.33 km/s, making it just shy of the escape velocity of the Moon. The Moon also allows for energy storage to be more efficient when utilizing a Flywheel Energy Storage (FES). FES works by spinning a rotor at high speeds, storing the energy. The vacuum and 1/6 of the gravity on the Moon increase the efficiency of a system like this by about 500%. (Miyano, 2018)

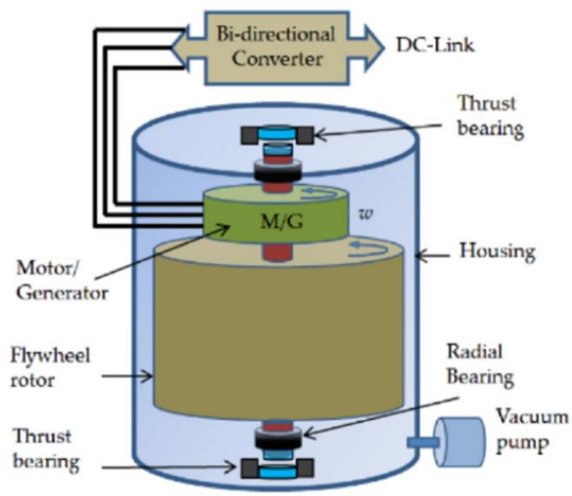

Figure 32: Flywheel Energy Storage System

Source: "Journal of Space Safety Engineering" (2018)

Retreived from https://www.sciencedirect.com/science/article/pii/S2468896717300617

An electronic rail system can be utilized to transport excavation robots, vehicles, material, and humans across the Moon. If we plan to colonize the Moon, transportation between outposts, bases, and colonies rapidly will be necessary. Using a form of MAGLEV rail system like this will increase speed and be more power efficient due to the possibility of powering everything from solar or fusion energy. Wheeled or tracked vehicles would be beneficial in close-range transportation, but due to the geography of the Moon and how easily it could be to get stuck in the fine sand or dust, a track between points of interest becomes not just more efficient but safer. Since the rail system is electric, it can act as a charging port for robots or rovers as well.

Lunar Electromagnetic Interceptor Launch Systems

Once the electromagnetic acceleration systems become perfected, they can be utilized to send small payloads to various orbits or Earth, thereby cutting the cost of shipping materials from the Moon to Earth. A current program is the Lunar Electromagnetic Interceptor Launch System (LEILAS). This system will serve the dual purpose of being a launcher for payloads into LEO and Earth-Moon Lagrange Point Two, and in emergency cases, planetary defense against asteroids.

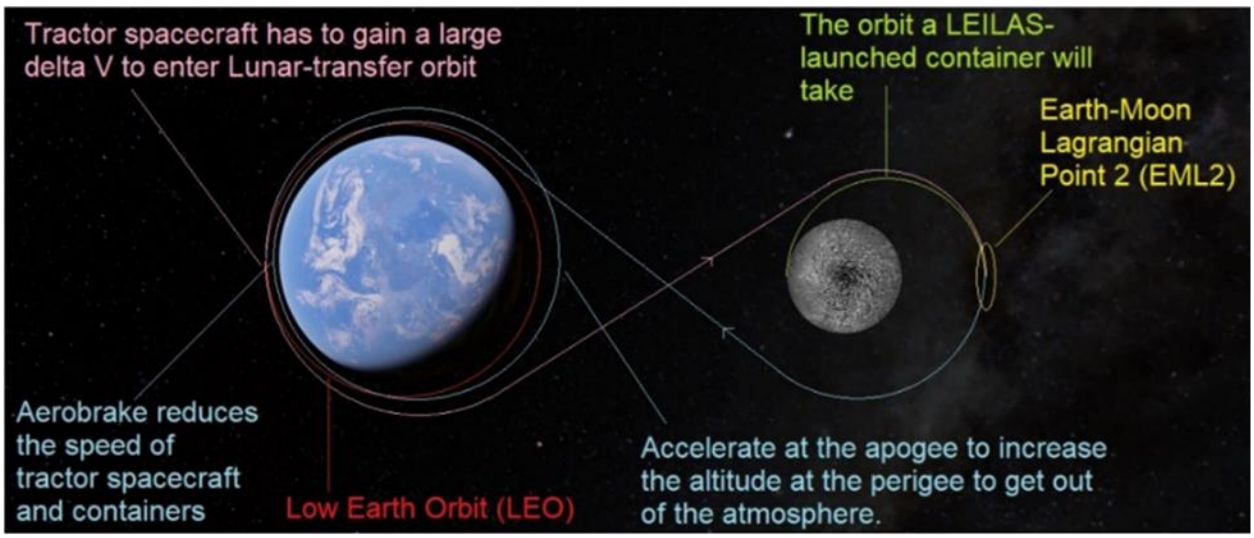

Figure 33: Lunar Electromagnetic Interceptor Launch System

Source: “Journal of Space Safety Engineering” (2018)

Retreived from https://www.sciencedirect.com/science/article/pii/S2468896717300617

Receiving adequate funding for planetary defense is difficult due to the rarity of asteroid impacts. This project allows for a dual purpose that would make funding far easier due to the ability to cut the cost of material transportation to Earth or space. This program will require large funding to get the construction and infrastructure built. It is estimated the overall cost would be 277 million dollars, with an annual operation cost of 10 million dollars. Once completed, LEILAS would be capable of sending a 1-ton container over 1716 times a year, drastically cutting costs by more than 91%. If the destination is EML2, there would be no need for a towing vehicle to gather the container and move it, resulting in the cost being only 0.6% than if it was to be shipped to EML2 from Earth using a Falcon Heavy rocket. (Miyano, 2018)

In emergency situations, LEILAS can be used to aid in providing mass for a kinetic impactor. The system will send 10 one-ton containers into EML2, where they will be received by a spacecraft. This spacecraft will then act as the kinetic impactor to disrupt the trajectory of the asteroid. This use would cut the cost of launching the vehicle, as it would be approximately 10-tons lighter during its launch.

Robots on the Moon

To promote discovery and exploration, humanity must extend its reach beyond the Earth. Not only do the discoveries have the chance to improve life here on Earth, the technologies made in the process will also benefit society as a whole. With this expansion into deep space, it is uncertain what risks our astronauts will be exposed to. It is unclear how harsh the effects of microgravity and radiation will be that far from Earth and outside the protective magnetic field. Due to current and future technology and innovations, we do not always have humans in the danger zone. The possibility of a human-robot system to work in cohesion is not only preferred, but I believe it is the only way.

Human-Robot Systems

A repetitive question being asked is who is better for space exploration: humans or robots? Both sides have strong arguments for advantages over one another. From face value, robots seem to be the obvious choice. As stated, the space environment is relentless. The lack of oxygen, the extreme temperatures, radiation, and the long travel time to destinations make it uninhabitable by humans without a certain level of technology. Robots can be given a task and accomplish said task perfectly and repetitively. It is also far cheaper to send an unmanned robotic crew over humans as no life support is needed. The robots just need the sun for power. Therefore, most of our space exploration has been accomplished through rovers or probes.

From a different perspective, humans are far better at exploring than robots. Humans are far more flexible in accomplishing tasks and making decisions. Yes, a robot can be programmed to do a specific task, but in the concept of exploration and discovery, that robot is actively looking for a specific thing and can easily overlook something if it wasn't programed to look for it. Also, while you may be saving money by not having to include a life support system on board, I would argue the scientific reward is increased with a human crew. This is due to our higher mobility in these types of situations. During the Apollo 17 mission in 1972, astronauts traveled 35.7 km. Even with a 30-year advantage in technology, the Mars exploration rover took eight years, from 2004 to 2011, to traverse 34.4 km. [3] Steve Squyres, the Principal Investigator for the Mars Exploration Rovers Spirit and Opportunity, stated "[t]he unfortunate truth is that most things our rovers can do in a perfect sol [i.e. a Martian day] a human explorer could do in less than a minute". (Crawford, 2012)

For these reasons, I strongly suggest a human-robot system. Just like the advantages of a multi-robot system. We are mutually dependent on each other in space exploration. Robots are a necessary part of helping humans in space. We need to consider both the pros and cons of each, and have the others fill in where it is necessary. Robots' robustness and ability to work around the clock can be adapted to compensate for the fragility of humans, while our critical thinking and higher mobility can be utilized to accelerate the expansion and oversee the operations.

As we progress into space, our current route is the best one. It is ideal to utilize robots initially to get a better understanding of the area, providing critical information to scientists and, in the end, reducing the risk to human explorers. After careful consideration and the risk being decreased, it becomes a better time to utilize humans to work within the safety area. Humans should mainly oversee operations and only take on tasks that are low-risk and high-reward, as robots are expendable. Even for jobs that are low-risk and low-reward, they should be taken over by robots. These jobs consist of everyday routine jobs that are easily achievable by robots, like farming, transportation of materials, and maintaining the area.

Artemis

NASA's Artemis program is planning to utilize robots not only on the surface of the moon but also in its planned space station Gateway. NASA recognizes that having a human presence in deep space for an extended period is currently not feasible, and that robots will be used to maintain the stations. They are currently planning to handle most of the necessary tasks through software, but for anything manual they plan to utilize a robotic arm system. Not only is this helpful to maintain inside the station, but it can mitigate the necessity of astronauts having to make spacewalks, as a robot arm could be autonomously controlled or teleoperated to fix an issue on the outer surface of the station.

Main Controller

The heart of the operation would be controlled by an Artificial General Intelligence (AGI) or strong AI. Unlike Siri or Alexa, weak or soft AI, an AGI is a theoretical form of machine intelligence that has the capabilities of human consciousness. [4] This would allow the system to complete complex tasks and adapt to the unknown of space travel. This system would have to be the main point of control over all the robotic systems on the base. It will monitor and send commands to the systems, allowing for true autonomy. An AI system would be able to monitor far more components at once than any human could possibly do. As this would be the most advanced portion of the base, it would require the majority of the power and cooling necessary to maintain its operating system, allowing for sub-systems to be less expensive. This main node could be adapted to the whole base as well. It can control all systems, keeping track of the safety and security of the humans on the base. Putting this amount of power in the "hands" of a machine would require this to be one of the more expensive and well tested components of the base.

As our capabilities increase and our lunar permanence shifts from an outpost to a full colony, I believe AI will be found everywhere. Like in a sci-fi movie, advanced AI will be in almost every electronic device, from the buildings themselves to every robot.

Reconnaissance

One of the first things that we tend to send to orbital bodies or space, such as the Moon, Mars, or orbits, is a robot. This allows an intelligent payload to be able to provide reconnaissance and collect important data before sending humans there. This also allows scientists to discuss if the trip is even worth pursuing. If a rover was sent to a location where we believe important resources are and it was unable to locate any through scans, this would save countless hours and funding by not having to send a human to make this discovery.

<u>Mining</u>

Robots can not only be used to deter missions, but they can also be used to complete them entirely. For mining for volatiles such as helium-3 for fusion, water for life support or fuel making, or even metals for construction, robots are an ideal solution. Robots can be equipped with various tools to accomplish an endless number of tasks. A robot can confirm volatiles in an area, then it could extract said materials and then transport them to a location. We can even spread the tasks out between various robots and create multi-robot systems. This will include a team of robots, each with a specific task. One robot will scout the area and locate volatiles. Another robot will receive the location of that material and extract it. Then a third robot will be ready to receive materials from the excavating robot and transport them. This system would allow for quicker locating, excavating, and transporting materials as all three tasks could be done simultaneously. These ideas can be seen in various NASA competitions, such as: The Space Robotics Challenge, where contests utilize a multi-robot mining system in a simulated Moon area to mine for the volatiles, or Lunabotics, where contestants build rovers that are meant to mine through various regolith.

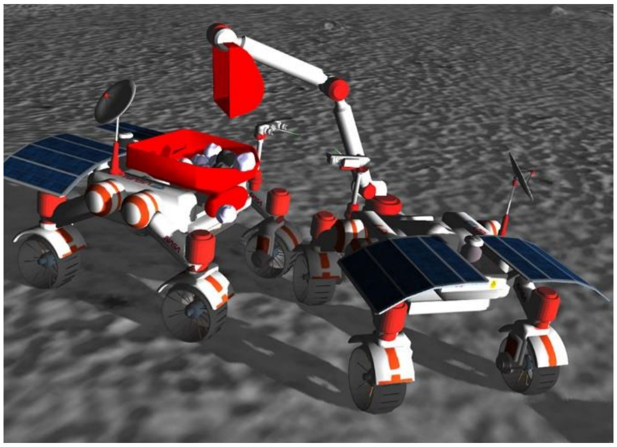

Figure 34: NASA's Space Robotics Challenge

Showing an excavator robot is giving voloatiles to a separate robot to transport it.

Source: "Create" (2021)

Retreived from https://createdigital.org.au/university-of-adelaide-team-third-prize-nasa-robotics-challenge/

Construction

Some ideas I believe to be necessary for future space colonization would be to utilize robotics in a type of swarm construction. For example, building a lunar base for a crew to live in during missions on the Moon. We could send a rocket carrying a payload of robots that would deploy on the surface and build the base before any humans left Earth. These robots can then be used to maintain and expand on the current base or build another outpost in a different location.

A current construction style seen in autonomous swarm robots called Termes. These robots are inspired by termites and are being produced by Harvard University. Each one of these robots acts independently from one another, but at the same time, in full cooperation to build the same structure. Through simple "traffic rules," these little robots are able to lay bricks down to build various structures without knowing the overall plans. (Connor, 2014) The reason for this type of swarm construction is that if one robot were to fail, it would not affect the end goal. The remaining construction robots would fill in without even knowing one of the other ones failed.

Figure 35: Termes

Source: "Independent" (2014)

Retreived from https://www.independent.co.uk/tech/scientists-believe-swarms-of-robots-could-help-build-base-on-mars-9126648.html

Robots can not only build buildings but can also be utilized in all types of construction. They can be building the tracks for transportation or the vehicles themselves. Robots can even be used to build other robots and fix them if needed. The versatility needed for all types of construction will result in multiple different robots with various dexterities and strengths. Heavy high-torque robots would be needed for land clearing and heavy lifting, while smaller robots would be needed to construct intricate systems like electronics or wiring of the bases or other robots.

With 3D printing on the rise, I think it would be a perfect idea to utilize this concept on the Moon. 3D printing can print anything from soft rubber to even cement buildings that could be utilized for protection from micrometeorites or radiation. It can be utilized in all aspects, such as initial construction, but also in the ability to print a piece needed for repair on the spot, which would be far better than having to send that piece from Earth.

Routine Jobs

As stated above, having robots take over the mundane jobs allows the astronauts and possible colonists to focus on more mission-critical tasks. Even on Earth, we find ways to utilize technology to make our days easier by having robots vacuum for us, keep our schedules, and for some, even drive them by utilizing self-driving cars. There is no reason robots on the Moon cannot continue to aid in everyday activities. Such as taking over jobs such as farming once it becomes easily maintainable. Current technology today alone can be utilized to keep track of farming by monitoring plant growth and even harvesting the crops. Autonomous transportation can be utilized to transport materials such as volatiles or even dispose of trash. With the majority of the work force being robots, it will only require a minimum of human workers to oversee these operations, or possibly step in if needed.

Figure 36: Robotic Farming

Source: "The Verge" (2019) Retreived from https://www.theverge.com/2019/5/2/18526590/robot-farming-startup-iron-ox-california-leafy-green-bianchinis

Concerns

Although I believe robots are an integral part of space travel and are key to colonizing the Moon. I do have strong concerns about a few issues. Even though robots are robust, I believe the Moon's environment poses a risk to the use of robots. Another major issue is that our current robotic capabilities may fall short of the necessary tasks.

Environment

One of the more apparent issues with the Moon's environment to the robots is the sand. 95% of the sand on the Moon is smaller than one millimeter, and 50% is less than 50 micrometers, classifying half of it as silt instead of sand. Sand on Earth is constantly being moved around by various atmospheric forces, causing the grains to be smooth. The lack of these characteristics results in the lunar sand being abrasive and full of sharp points. To make the sand even harder to manage, the Moon's sand is very magnetic, causing it to be highly attractive towards any object like motors or gears. This makes designing robots and vehicles very particular, as they will have to be completely sealed off in hopes of mitigating the motors or electronics failing. This fine silt also poses a risk to the rover's tires, losing traction, causing the robot to be stranded. The most recent rover sent to the Moon, Chinese Yutu, proves how this can pose an issue. The rover became immobile due to "mechanic control abnormality due to the complicated lunar surface," according to Chinese officials. (Miyano, 2018)

Another issue I foresee is the fluctuation in temperatures during the lunar days and nights. The robots will need to be designed in a way to handle very hot temperatures during the day and very cold temperatures during the night. Higher altitudes can reach a boiling temperature of 392 degrees Fahrenheit, while some craters reach close to -424 degrees Fahrenheit at night, far more extreme than Mars. This results in strong consideration of materials used to construct these robots, and if certain robots will only be able to stay in certain areas, as they are designed to handle only one side of the extremes. Even then, current robots, like the rover on Mars, cannot withstand such cold temperatures; they must contain their own heater. (Masten, 2022)

A Moon's day is much longer than ours, resulting in roughly 14 days of sunlight and 14 nights of darkness. The combination of extreme cold and darkness for 14 days poses a concerning risk to power for the robots working on the Moon. Luckily, I am not the only one who finds this issue concerning. Masten Space Systems is working on a solution that might solve both issues. Their Nighttime Integrated Thermal and Electricity (NITE) system can act as a battery and a heater, producing 1900 Wh/kg for the robots. As a result, it is 7x lighter than standard lunar night battery options while also lasting 12+ months. (Masten, 2022)

Current Capabilities

There is no doubt that the robotic industry is on the rise. It is currently stated to have a compound annual growth rate of around 12%, with an expected worth of around 260 billion dollars by 2030. (LillyWhite, 2021) It is amazing what technology we currently have and the capabilities robotics has at this moment. Though on the rise, I do not believe we are at the level necessary to make colonization at the level stated above plausible. According to our current projections, the Artemis program will not have astronauts on the Moon until around 2024–2025. It will be years afterward until I foresee the need or possibility of those types of robots to help sustain a permanent lunar presence. My worry is that as the technology increases to meet the needs, there will not be enough time to properly adapt and test the technologies as we go or that autonomy will be far delayed in space travel. To accommodate this, humans will need to take the lead while letting robotics fill in the gaps where it is necessary or possible.

In the Gateway section, it was acknowledged that they plan to utilize technology such as software and robotics to keep the station autonomous as much as possible. The Gateway is set to launch in 2023. It was stated that the Canadarm3, which will be utilized on the station, has not been developed yet. The system is not planned to be shipped to Gateway till 2027. (About Canadarm3, 2022) This timeline makes it miss the first use of the Gateway by Artemis III by a few years. This is how I foresee the delay of robotics occurring. Humans will be used to get everything up and running, then slowly adapt to robotics where it is possible.

Although we have been making extreme strides in technology and concepts such as deep learning, planning, neural networks, and other forms of computer intelligence, there is much more to learn to help model and simulate human consciousness. It is expected, though, that an AI will be strong enough to pass a "consciousness" test by around 2060. (English, 2020) This is also around the time I expect a consistent lunar presence to occur. But I still believe it is far more likely to have multiple soft artifice intelligences individually in control of separate entities. These systems would be like what we have today, such as Siri and Alexa, but far more advanced due to the 40-year advantage of constant innovations. Soft AI would still have a strong advantage in monitoring and keeping track of systems compared to a human worker, making them more than acceptable for use.

An AGI under control also poses various risk factors. Although its initial directive is to keep track of a certain area, such as construction, it could change its mind and decide it wants to build something completely different. Due to its ability to adapt and think for itself, it poses the ability to change its own goal, which can pose a security risk to humans relying on it.

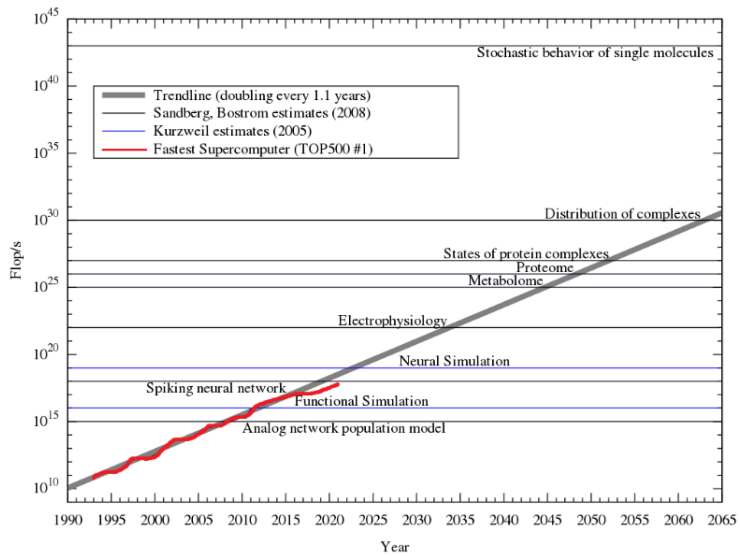

Figure 37: Estimate of Processing Power Needed to Emulate Human Brain

Source: “Wikipedia: Artificial General Intelligence” Retreived from https://en.wikipedia.org/wiki/Artificial_general_intelligence

Sociopolitical

The Outer Space Treaty of 1976 provided a foundation for international space law. This included some key points that would result in the Moon having its own sociopolitical environment. The treaty stated that outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means. With a full colony being formed, what country would be in charge? Will the Moon become its own political entity? There is no doubt crime will follow humans to space, but with some of the materials being rare and valuable like helium 3, who will be the ones to oversee operations and make sure crime is kept low? The Outer Space Treaty forbids any form of military base or establishment to be on the Moon. Would this result in the Moon requiring its own military or police force to protect its colony?

There is no doubt that workers from multiple nations will be on the Moon. With work comes the form of payment. In what currency will they be paid in? Will this result in a new form of currency or the use of purely digital forms such as cryptocurrency?

With the possibility of a new life, a new government, economic development, and more. How will the new life on the Moon affect life on Earth? All these questions make us question how something unprecedented like this would be handled and its effects on society. With most things unprecedented, it lays the structure for later use in similar scenarios. We must be careful about how we handle the Moon situation, as it will have a direct impact on how future human expansion is handled.

Initially

Before any colony is made, there is a race that is occurring. There is more to the Moon than just expanding humanity. The Moon provides precious and rare volatiles that multiple nations hope to acquire for new technology. One of the major ones is the use of helium-3 as a key element in the possible creation of a fusion reactor, which as a result would create very efficient and renewable energy. It is also apparent that some areas of the Moon are better real estate for sunlight and water, which are crucial for current life support. This results in a race for those areas.

Although the Outer Space Treaty forbids nations from claiming areas, it fails to consider private companies. This allows for private industries to set up ground and mine areas and do with the materials as they please. As a result, the commercialization of space will be led by the private sector at first. This can be seen in the U.S. Commercial Space Launch Competitiveness Act, which facilitates a pro-growth environment for the developing commercial space industry by encouraging private sector investment and promoting the safety and right of U.S. citizens to engage in commercial exploration and recovery of space resources.

With countries finding workarounds to allow for private industry to claim and utilize space resources, I am sure competition will rise and result in tension as certain countries try to monopolize certain resources. This will demonstrate the need for a "Moon Treaty, or Accord," to more directly lay out regulations and policies that all nations agree on in order to promote a safe and promising future for all humankind on the Moon.

Political

As time progresses and there are more than just a few private companies working on the Moon, there will need to be a shift in governance. Smaller bills and rules being passed through things such as the Artemis Accord work for smaller groups such as crews and bases, but more structure will be needed as these expand to communities or societies.

Government

Currently, outer space will act similarly to international water. Though there are some policies in the Outer Space Policy and the United States Space Policy that act as deterrents for misuse of space, it will not be enough as human expansion increases. Conflicting ideas will increase as the number of members increases. This will result in the rule of law being essential for the stability, longevity, and safety of a society. With the Moon being a separate celestial body from Earth, there is no doubt the colonists would see themselves as separate, independent entities.

It is proven through history and everyday scenarios that we are a political species. Productivity and safety increase when a form of hierarchy is in place. This can be seen with sports' captains, team projects, business, and everyday government. A leadership will also provide unity between each lunar base, allowing for an equal amount of input from all bases.

Originally, the Moon will only be inhabited by those who can help with the tasks needed. This will include mainly scientists, engineers, and medical personell. This will initially lead to expertise and more skills being charged, with the view of progression and exploration of humanity. As the lunar presence becomes more permanent and the majority of the Moon will have some sort of occupation, the political view may switch from exploration and discovery to more of a common view of keeping the colony sustained and safe.

Law Enforcement

As stated, the Moon is considered to be international territory and the Outer Space Treaty forbids the occupation of weapons and military bases. This poses a risk as the Moon becomes more habitable. Initially, the private companies will be overseen by the home nation and will be held accountable. As expansion increases and the number of people increases, there needs to be some form of force to help keep the area safe. Humans are an imperfect race, and all forms of crime will follow from Earth to the Moon. With it being international territory, it will be much harder to mitigate crime from Earth.

This will result in a judicial system with law enforcement with the jurisdiction to enforce the laws on the Moon. Without this, when a crime is committed, it would leave it to the rest of the colony to handle the crime, which may lead to more than imperfect detainment and punishment. Having this system set up will allow for the use of trained specialists and prison systems on the Moon instead of having to transport criminals to Earth.

Currency

Initially, crews will not need to have any money on hand as all their supplies will be supplied from their home nation. As the possibility of connecting different nation bases grows, it will become more difficult to buy things with Earth currencies. Though some currencies on Earth can be used in multiple countries, most of the time they will need to be exchanged. This will be inconvenient in cases where a colonist can possibly walk 10 meters and be in a lunar module from Japan or 10 meters from a UK module. Due to cosmic radiation, chips and magnetic strips used in credit cards will not work. (Christensen, 2007) Along with these issues, and as the colonies become independent from their original home nation, I do not believe they will want their finances affected by Earthly issues.

Britain's National Space Center also agreed with this, as they developed a new currency for inter-planetary travelers. The QuasiUniversal Intergalactic Denomination (QUID) is specifically designed to withstand space travel. It is designed to contain no sharp edges or chemicals that could pose any sort of risk through space travel. (Christensen, 2007)

Figure 38: The QuasiUniversal Intergalactic Denomination

Source: "Space" (2007)

Retreived from https://www.space.com/4454-scientists-design-space-currency.html

Though I agree a new form of currency is necessary, I do not believe a QUID will be it. It is currently a physical coin, which is bulky. I believe a digital currency will be far more efficient and sustainable.

Personel Diversity

As stated initially, the personell on the Moon will be individuals who are key to the sustainability of the mission. Early on, the mission will be more scientific as the astronauts will be using the Human Landing System as an outpost and will be conducting experiments and research. To account for the unknown, the initial group will need to be highly trained in a variety of areas, including their primary roles, as well as second-hand knowledge of medical aspects, engineering, and other concepts. As more infrastructure is needed during the transition to a more permanent base, various types of engineers will be needed to build the modules and maintain the robotic systems necessary. With more room, primary medical professionals will need to be on hand in case any injuries or unknown biological effects occur.

As the sustainability infrastructure is being worked on, biologists, water system engineers, hydrogeologists, botanists, and more will be necessary to build up a sustainable life support system. Though we know the Moon contains water, it will need to be treated and processed for drinkability, and a botanist will be necessary for aspects such as using algae for oxygen production or growing crops for sustainability. During this shift, I also believe a security force will be necessary, as the number of people has increased enough to warrant one.

With the growth of the base and its shift to a full colony, more labor workers will be needed to maintain the infrastructure and keep track of the systems. This can be seen in everyday maintenance such as trash disposal, cleaning of the base, and maintaining systems such as solar panels, vehicles, and electronic systems. As I foresee the use of robotics to take a little more time to fully be utilized throughout the base, human workers will be necessary. As the number of individuals is increased, families will start to join them, or even start on the Moon. This will lead to the necessity of all levels of doctors, such as pediatricians, teachers for schools, workers for things such as stores, and all other day-to-day necessities. One key specialist that will be needed is a nuclear engineer, as around this time I hope we have properly conducted enough Earthbound experiments to get a fusion reactor running efficiently enough to allow for the colony to utilize this power method along with its standard solar power.

Earth - Moon Relationship

Initially, the Moon colonies will strongly depend on Earth. The majority of their supplies will be shipped and funded by Earth. Earth, as well, will strongly benefit from the discoveries and exportation of resources from the Moon. Resources from the Moon, such as helium-3, will be crucial for Earth's next energy source.

As time progresses, the Moon will become increasingly more independent. For the Moon's ability to become a colony, it will need to be mostly self-sustainable. Due to this, I believe it will reach a point where both Earth and the Moon become reliant on each other equally and financially. As stated, the ability to launch from the Moon is far more efficient than from Earth. This will result in the Moon being a key space port for further travel while also providing defense capabilities for Earth from foreign objects.

With the Moon containing a theoretical endless supply of helium-3 and a vast number of other materials such as titanium, the economic system of the Moon will heavily rely on commerce. This commerce will not only be to Earth, but as expansion occurs, it will reach Mars and beyond.

Piracy

Modern piracy is still an occurrence across the oceans of the Earth, with over 100 attacks on ships per year. (Statista, 2022) Modern day pirates do not always attack ships; a large number of incidents involve them vandalizing and stealing from oil pipelines. In 2016, it was estimated that $1.5 billion a month was being stolen in Nigeria alone.

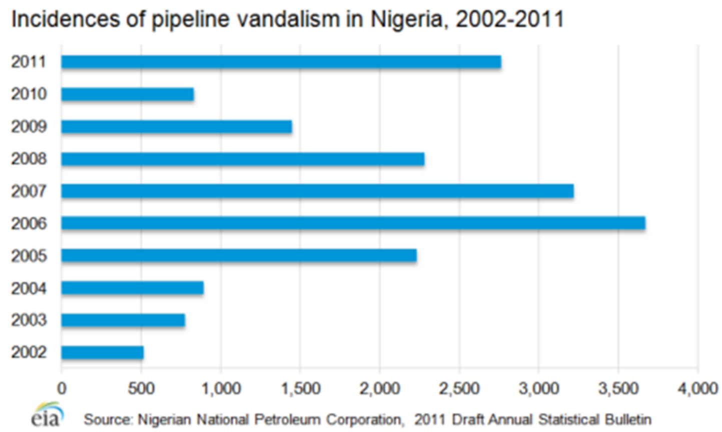

Figure 39: Pirate Vandalism on Pipeline

Source: "Nigerian National Petroleum Corp." (2011)

Retreived from https://en.wikipedia.org/wiki/Piracy_in_the_21st_century#/media/File:Pipvangulgui.png

A science fiction idea that has a strong chance of becoming reality is space piracy. As time progresses, the lunar presence becomes a more common occurrence. I have no doubt that space piracy will occur. One form will consist of stealing resources such as helium-3 and even water. With the majority of the labor being done through robotics, it will be far easier for a crew to sneak in and out with some stollen resources. Other forms of piracy can be the stealing of the mining equipment itself or hacking into critical mainframes for data or ransom.

This leads to not only the Moon needing a police force to keep its areas safe, but the possibility of an interstellar force to protect transportation ships and protect cyber infrastructure similar to the duties the United Space Force has for America.

Biological Evolution

In the far future, after many generations of colonists, it will show the evolution capabilities of humans. On Earth, the evolution of humans can be seen as they traveled across the world and their bodies adapted to the environment. The occurrence on the Moon I believe will be far more drastic than any seen-on Earth.

The effects of microgravity are already being felt by astronauts in space currently. Astronauts must follow a strict diet and exercise routine to maintain muscle mass, as microgravity causes deteration faster than on Earth. NASA states "weight-bearing bones lose on average 1% to 1.5% of mineral density per month during spaceflight." (Abadie, Cranford, Lloyd, Shelhamer, & Turner, 2021) Also, the body's fluids tend to shift towards the head, which results in extra pressure on the eyes that can cause vision problems. NASA is constantly trying to analyze these issues and adapt to mitigate them. This involves things such as workouts and diets to increase muscle mass, pressure sleeves on the thighs to keep fluid in the lower extremities, and even medication such as potassium citrate to combat psychological changes.

Though microgravity is a danger, radiation is one of the main health hazards to consider when traveling outside the Van Allen Belts. As the intensity increase as you ventur out from the protection of the belts, the radiation can have sufficient energy to change and break down DNA molecules, damaging or killing the cells resulting in long term health problems. (Gov. of Canada, 2006)

The lunar environment will likely mold its inhabitants to better survive its ecosystem. The Moon has only 17% of the gravity on Earth, and we have seen the deterioration of the muscles and skeletons of astronauts in space over time. It is also known that radiation will be far worse on the Moon than that seen on Earth or LEO. This will lead to the colonists' living mostly indoors of thick-walled buildings or underground, reducing their overall vitamin-D intake. These situations, and more, all result in various effects and changes on the body. To survive on the Moon permanently, the colonist bodies or our technology will need to adapt to those conditions. As seen with current astronauts, once on Earth they must go through rigorous physical therapy to adjust. If the colonists' bodies are adapted to the lunar environment, they might not be able to come back to Earth.

These adaptations will lead to a new sub-species of humans. It is uncertain if our bodies will change to combat these issues or if they will conform to them. For example, will the colonists be born with thicker bones to try and overcome the bone density issue, or will they just be thinner due to it? Will people who are more adept at handling radiation pass down these genes? An outcome of too much radiation can result in cancer or even sterility, making it harder to reproduce on the Moon. (Gov. of Canada, 2006) It is hard to dictate the outcome of how evolution will advance our species, but I am certain it will.

Genetic Testing and Modifications

As noted, space will have drastic effects on the human body. With current technology, will we have to wait for evolution to take its course to create a sub-species that will be better adapted for the Moon's environment? Currently, there is a concept of designer babies. This is where an embryo that has been screened for predetermined characteristics is selected or rejected for implantation. This is currently a way to help avoid giving birth to a baby that might carry certain diseases or unwanted genetic conditions.

As this technology and others, such as CRISPR (gene editing), increase, it poses an ethical issue. Will scientists expedite evolution in humans to help them adapt to the Moon? Doctors and scientists can pick and choose desirable traits that may better adapt to radiation, microgravity, and other Moon attributes. This leaves a debate on the ethical issue of whether scientists should be able to play with evolution. If it is ethical to be able to predetermine if someone should be living on one celestial body or the other? I believe if the individual would have been born on one celestial body such as the Moon, that giving that individual qenes that will benefit their quality of life, it should be a concept considered.

CHAPTER 4: CONCLUSION

The idea of space travel, living on a different celestial body, and discovering the unknown has always been a science fiction fantasy. Space is truly humanity's final frontier. The idea of being able to colonize various planets and travel between them is a fascinating feat. Since the iconic Apollo missions that resulted in a total of 12 astronauts stepping foot on the Moon, no human has ever gone back or beyond. The Artemis program is set to change this much sooner than anticipated. Not only is the Moon the first step to test humanity's expansion and ability to colonize a celestial body, but it also holds the key to preserving and sustaining humankind.

Everyday, humanity is at risk of possible extinction. This can be seen in the current global climate crisis, viruses, nuclear war, and catastrophic astroid impacts. This report proves the Moon is the closest celestial body that will help sustain and preserve the human species. Current research shows fusion reactors are essential to solving our energy crisis as they produce little to no harmful bi-products, and the concept of utilizing helium-3 mined from the Moon makes it renewable. Having humanity spread across celestial bodies allows for the preservation of humanity in case of any apocalyptic event on Earth. In situations like an incoming asteroid, the Moon presents the perfect location to launch interceptor rockets to prevent a collision.

This evidence shows that not only will the Moon present solutions to the previously stated problems, but it has other strong advantages that will excel humanity to spread throughout the cosmos. As stated, with the perfect location to launch interceptors, it is perfect to launch crewed rockets as well, expanding the rocket's reach. This not only makes the Moon a perfect location to test new space equipment and to set a precedent for the possibility of off-Earth colonization, but also a perfect launching point to other celestial bodies such as Mars.

The exact details of human expansion has endless results. Will we get to a point where our present day looks like it was taken out of science fiction such as Starwars and Startrek? Will a lunar permanence consist only of robots? The answers are unclear, but the Artemis program is one small step in the right direction to solving what humanity's future looks like. Though there is still much work to be done towards this front, this endeavor may be the salvation of humanity.

CHAPTER 5: RECOMMENDATIONS

This report focuses on bringing forth a broad range of current space travel topics. My goal was to benefit this field as I tried to cover various important topics to act as a review for future researchers. This includes everything from mining of helium-3, fusion reactors, current missions, advantages of the Moon's environment, and more. This leaves a broad start for future research to take one of these topics and dive deeper, providing a more in-depth report.

There are a few ideas that can be expanded on, such as the feasibility and cost of starting the mining process and how much it would cost to sustain such a large enterprise. This would include the amount spent on equipment costs, how much equipment is needed, how many trips are needed with current technology to send the equipment to the Moon, and more. As helium-3 is such a valuable asset for creating greener energy, there will be a large upfront cost to get it started.

There are other options as well, such as focusing on the socio-economic and political aspects of a colony. There is no doubt that a colony on the Moon will be far different as it will need to adapt to its harsh environment. Life-support items such as food, water, and oxygen will not be readily available. How would that affect a society from a political and economic standpoint? This report briefly covered how micro-gravity and radiation may affect humankind's biology and the ethical standpoint of gene editing, but this concept can be expanded on even further.

As a science fiction fan, the concept of robots being at the forefront of space travel seems like common sense to me. As a robotic engineering student, I know the hard work that will be needed to expand the robotics field to get it to a point where I believe it will need to be to provide these benefits. The robotic field is rapidly changing. New technology is constantly evolving, making something science fiction today, plausible tomorrow. A report can go deeper into the current technology we have and what is currently in the works in the field of robotics.

Another final recommendation on where to lead this project is where to next. We know for a fact that we will be going to the Moon. The Artemis program has already declared its mission objectives. It is speculated that after the Moon, the next stop will be Mars. If that is the case, how will the concept of lunar permanence be adapted to a martian permanence? With the increase in technology, will we look beyond Mars and go to a better planet? We are at an exciting time in human history where technology is rapidly increasing, making it unknown what we will be capable of as time progresses.

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APPENDIX A: AMERICAN ASTRONAUTICAL SOCIETY INTERVIEW

Guest

- Brett Alexander - VP, Gov. Sales, Blue Origin
- George Pollock – Director, Astrodynamics Dept., The Aerospace Corporation
- Ben Reed – Co-Founder & CTO, Quantum Space

George Pollock

- Once you reach GEO, there is not much more energy needed to reach Cislunar Space.
- That extra room is 1 to 1000 more exploration in volume.

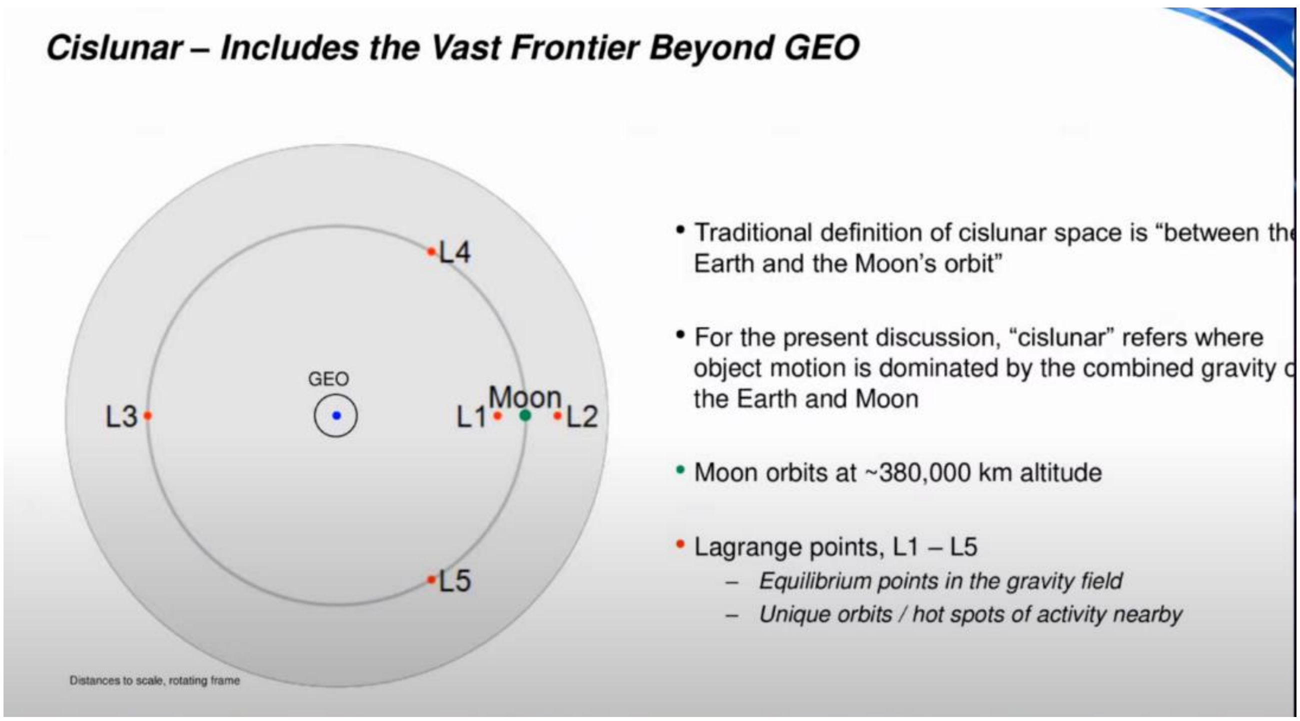

Figure 40: Lagrange Points Around Earth and the Moon

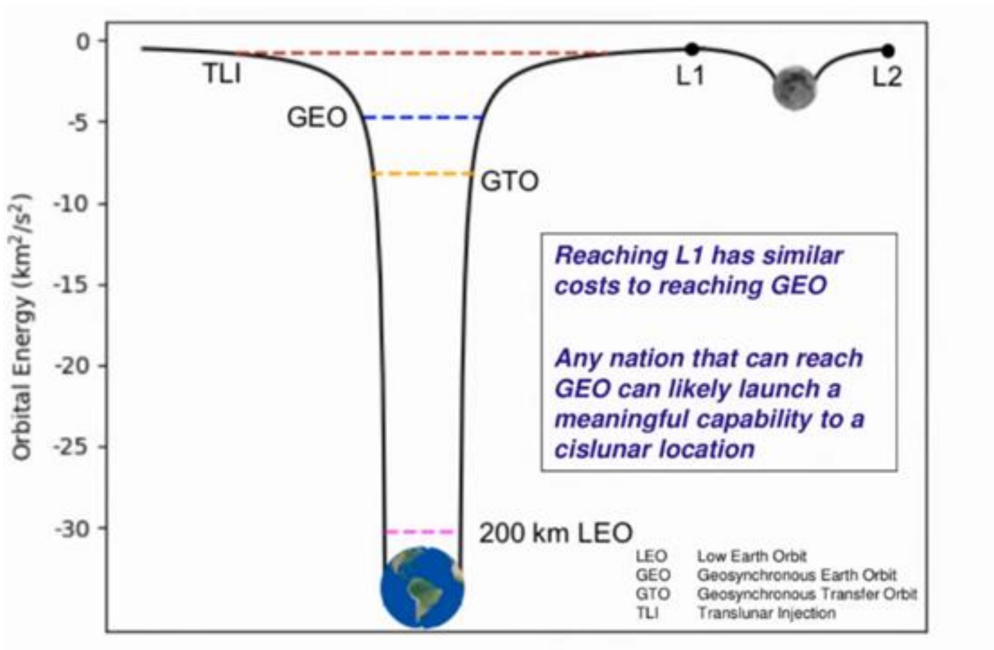

Figure 41: Energy Needed to Reach LEO and beyond

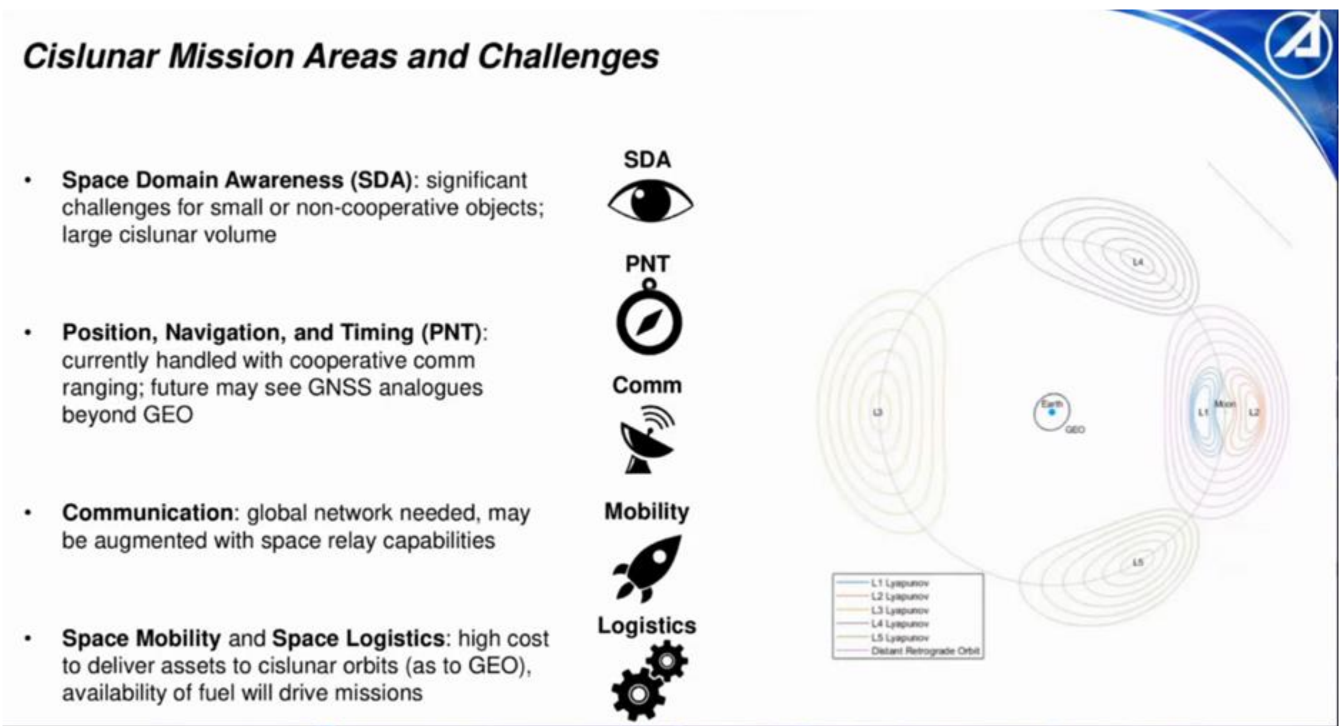

Figure 42: Cislunar Mission Areas and Challenges

Brett Alexander–

- Goal is Lunar Permanence – constant presence on the moon.
- Key Issues
  - Cost
  - Safety
  - How to gather the resources once we are there.
- Blue Origin is creating the Human Landing system for Artemis.
  - NASA wants four humans on moon for 30 days

Ben Reed–

- Their company is creating a small robotic "satellite" in cislunar space in 2025-26
  - Location would be in L1 Lagrange point from earlier figure
  - Gather Data
  - Host payloads and Tests
  - Deploy Satellites
  - Logistic Services
- My issue, he mentions after payloads reach the satellite, they will be sent on a garbage orbit, leaving space debris.

Discussions

- Communication
  - Intuitive Machines has partnered with companies that own radio satellite dishes and telescopes like the Parkes radio telescope, to be used for lunar communication networks.
  - CSIRO (The Commonwealth Scientific and Industrial Research Organization) Australian Gov. Company. Signed 5-year agreement with Intuitive Machines to support lunar missions.
  - Lunar Telemetry and Tracking Network (LTN)
  - Send and receive from moon in less than 4 seconds
  - https://www.intuitivemachines.com/post/intuitive-machines-adds-legendary-telescope-to-its-growing-lunar-telemetry-and-tracking-network

- Total of 18 nations so far on Artemis Accord
    - "The purpose of these Accords is to establish a common vision via a practical set of principles, guidelines, and best practices to enhance the governance of the civil exploration and use of outer space with the intention of advancing the Artemis Program."
    - Also talks on Space resources
    - https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf

    - Signers
        1. Australia
        2. Bahrain
        3. Brazil
        4. Canada
        5. Israel
        6. Italy
        7. Japan
        8. Korea
        9. Luxembourg
        10. Mexico
        11. New Zealand
        12. Poland
        13. Romania
        14. Singapore
        15. Ukraine
        16. United Arab Emirates
        17. United Kingdom
        18. USA

- Cooperation between agencies, Nations, and Companies are key.
- Concerns
    - How would we rescue or how quickly we could rescue Astronauts that far out?
    - Sustainability of a Lunar Presence?

APPENDIX B: GLOSSARY OF ACROYNMS

AGI	Artificial General Intelligence
CFS	Commonwealth Fusion Systems
CM	Crew Module
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CSA	Canadian Space Agency
DART	Double Asteroid Redirection Test
DRO	Distant Retrograde Orbit
EMALS	Electromagnetic Aircraft Launch System
FES	Flywheel Energy Storage
HALO	Habitation and Logistics Outpost
HEO	High Earth Orbit
HLS	Human Landing System
ICPS	Interim Cryogenic Propulsion Stage
ILV	Integrated Lander Vehicle
ITER	International Thermonuclear Experimental Reactor
IQP	Interactive Qualifying Project
LAS	Launch Abort System
LCR	Lattice Confinement Reaction
LCRT	Lunar crater Radio Telescope
LEILAS	Lunar Electromagnetic Interceptor Launch System
LEO	Low Earth Orbit
LOLA	Lunar Orbiter Laser Altimeter
LRO	Lunar reconnaissance Orbiter
MAGLEV	Magnetic Levitation
NIF	National Ignition Facility
NITE	Nighttime Integrated Thermal and Electricity system
NRHO	Near-Rectilinear Halo Orbit
PPE	Power and Propulsion Element
QUID	QuasiUniversal Intergalactic Denomination
SEP	Sun Emitted particle
SLS	Space Launch System
SM	Service Module
SOFIA	Stratospheric Observatory for Infrared Astronomy
TLI	Trans-lunar Injection
VIPER	Volatiles Investigating Polar Exploration