Primary Lunar Base Design Proposal and Technical Report

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Abstract

Regarding the creation of a permanent base on the Moon, this report examines the design of a proposed lunar base and the challenges it will face. Recognizing the dangers of the environmental conditions of the lunar surface, the proposed design utilizes the environmental features present to counter many of the common issues that would face astronauts living at the lunar base for extended periods of time by being located inside of a lava tube. The proposed base follows a 10-year time frame to completion including the teleoperated preparation for the arrival of a manned mission, the initial and primary crew, and the subsequent arrival of more crew following the base’s designation as habitable. During this time, the crew would operate to construct a 3D printing solar sintering device that would utilize regolith in order to prevent large transportation costs of materials in order to finally prime the base for continued manufacturing. The report also recognizes the importance of maintaining a crew and setting precedent for international relations in space, as well as the large role that the proposed base will play in future missions to Mars and the collection of resources for use on Earth.

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With the arrival of humanity onto the doorstep of deep space during the Apollo era of the past 20th century came the simultaneous notion of the power of humanity as a species. The ability to venture into the most extreme environments undoubtedly has been most commonly cited as the current crowning achievement. Yet, for all of the value placed on these lunar missions, humanity has not yet become truly settled in the fathoms of space. As expectations and goals have expanded, it has thus become critical to set up a more permanent settlement of the Moon in order to realize future missions to Mars and, ultimately, beyond. Creating a presence on the Moon will include challenges past those of the Apollo missions, requiring facing the dangers of extreme temperature variability, radiation, and dependency on a distant Earth. However, by facing these challenges, the primary lunar base will not only be equipped to survive on the lunar surface, but also primed for truly becoming independent, expansive, and fundamental in reaching Mars. With the proposed primary lunar base design, the aforementioned obstacles will be faced with the unique resources of lunar soil, resources, and geology to offer astronauts the long-term safety that a base requires while pursuing the explorative nature of humanity as a whole.

The return of humans on the Moon for a more extended period of time will create many problems that must be provided for through any proposed lunar base in order to ensure the ability for permanent residence on the lunar surface. Certain challenges, including providing food, air, and water to such a distant body reliably, will be similar to those faced by astronauts aboard the international space station or at least problems that have working solutions implemented in space. However, being on the Moon will come with problems that are more unique to the lunar surface or more extreme than those on Earth. Specifically, any lunar bases will have to be resistant to incredible variations in temperature in the hundreds of degrees, jagged micrometeorites, and radiation attempting to bombard inhabitants with doses far beyond healthy levels (Lewis, n.d.). The proposed lunar base will combat all of these difficulties by utilizing the beneficial features of the lunar surface to its advantage. Firstly, the lunar base will be located in the northeastern sector of the Philolaus Crater, inside of the identified lunar lava tubes by the Lunar Reconnaissance Orbiter, as long as water ice is discovered (Lava Tube, 2018). These lunar lava tubes offer a myriad of benefits for long term habitation on the lunar surface by entirely eliminating or heavily mitigating the aforementioned issues. Aside from blocking radiation due to the density of the regolith between the sun, which emits most of the radiation, and the base, lava tubes also offer shielding from the temperature variations seen elsewhere on the lunar surface which thus allows for constant livable temperatures (Lewis, n.d.; Soderman, n.d.). Positioning inside a lava tube also protects from micrometeorites and, with all of these benefits, dramatically decreases the need for shielding, specialized technologies, and their associated weights (Soderman, n.d.). The proposed lunar base will revolve around operations inside of the lava tube in the Philolaus Crater due to its ability to allow for extreme environmental benefits. Aside from the environmental benefits, the lava tube will also offer one of the most critical resources for human exploration by likely containing water ice due to the evidence of water ice in shadowed craters at the Lunar poles and the presence of ice in similar lava tubes on Earth (Lava Tube, 2018). Water will not only play a large role in allowing the astronauts to be sustained, but will also offer fuel due to the hydrogen produced by electrolysis. This fuel will be useful for powering exploratory vehicles without heavy batteries. Alternatives to solar power will be especially vital as lunar day/night cycles are far longer than those on Earth and the ISS and will leave the base uninhabitable for extended periods of time, directly countering the desire for a permanent presence on the Moon. With the location of the lunar base set inside of the lava tubes of the Philolaus Crater, astronauts on the Moon will not only be able to access the resources they need for daily operations, but will also gain invaluable protection from the primary dangers of lunar habitation.

Building off of the benefits provided by the lunar lava tubes, the lunar base will be constructed in order to optimize the base for long term habitation, continued usefulness, and ease of construction. The construction of the lunar mission will begin following extensive research confirming the location of water ice inside the lava tubes by both satellites observing the lunar surface and a manned exploration by an Artemis mission. Following the completion of these research missions, progress on preparing the lunar base shall be made with the delivery of bulldozing robots operated from ground stations, which work to both bring powdery material for construction of the base near the lava tube and also create sintered pathways that prevent damaging regolith from being brought inside the completed base due to the health hazard it poses (Wilson & Wilson, n.d.). This initial portion of the mission will begin no later than 2035 to prepare for the arrival of astronauts. The first manned mission for the lunar base will take place in 2040 following the arrival of necessary parts, including the printing devices for base construction and hydroponic devices for agricultural purposes. This mission will land a habitable module where seven astronauts will live until the lunar base begins construction and becomes habitable. Astronauts will then start on the assembly of the base, which will likely take a full year in order to fully finish. Utilizing a lightweight gantry based on pulleys, a large magnifying lens will be moved to 3D print lunar regolith deposited by a material delivery head, attached to the same gantry, in order to sinter regolith into walls. Regolith not only offers a material that has been analyzed for construction of extraterrestrial bases, but also releases capturable oxygen when heated and treated with the water that shall be used for concrete construction (Aulesa & Casanova, n.d.; Allen, n.d.). The use of 3D printing has already been proven to create habitable structures with the properties needed lunar habitation, allowing for cost savings as material does not need to be brought to the Moon (3D Printing, n.d.). Mimicking a honeybee hive, 3D printed regolith will create rooms for inflatable habitation units, which are cheap to transport due to their weight, to be inserted inside of the structure while being additionally shielded from micrometeorites by the outer regolith layer. The proposed lunar base will focus on the manufacturing of sintered bricks for use in constructing future bases and expanding further into the lava tubes. This manufacturing ability will be retained by stopping the vertical expansion of the lunar base in order to allow for a flat “roof” that acts as a 3D printing bed. With the completion of the roof, the astronauts will be first able to move into their lunar base and begin their operations, which will switch from focusing on maintenance of the manufacturing device and collection of materials to sustaining themselves without supplies from Earth. These astronauts will begin utilizing cultured meat and hydroponics to sustain themselves due to the ability of these methods of generate food without the use of many resources and their proven ability in microgravity (Kaplan, 2022). Astronauts around the 2045 mark will also be able to begin working towards continuing the expansion of the base with the arrival of more astronauts as the lunar base transitions to independence from Earthen supplies. Operating under the unique conditions of the Moon, the astronauts completing their allotted stay on the lunar surface of 5 years will also begin to return following their commendable service in transitioning the lunar base from an outpost to a base.

With the involvement of the initial crew on serving to create a functional and habitable base on an extraterrestrial body, the personnel selected will be indispensable and be cornerstones of the entire mission. Since the proposal for the lunar base relies heavily on semi-automated and teleoperated robotics, these personnel will hold more of a role in maintenance than construction even in the phase most heavily associated with the construction of the lunar base. Primarily, the personnel will focus on assisting technologies present on the Moon to continue operating quickly in order to finish the base as early as possible. Furthermore, the personnel will also be able to help with any issues that arise during the mission with heavy focuses on issues that would be unsolvable from the Earth, such as mechanical faults, after they complete setting up the 3D printing gantry. Alongside these tasks, the crew will also prepare for making the base sustainable by initializing experiments during the early stages of the mission to create food and water. Since these tasks will all be shared by the crew, each of the members will be trained on all tasks in order to provide redundancy for the loss of a member. The loss of a member would not be of critical concern since any member with medical issues will be sent to Gateway, or possibly even directly to Earth, while other crew members could take their spot due to their matched training. However, since the crew members will be extremely far from Earth, two medically trained crew members will be part of the original crew for any unlikely medical mishaps that occur. Crew members will also be kept in good health through training similar to that done on the ISS. Furthermore, members chosen will be between the ages of 35 and 40 in order to both allow for teamwork and to prevent long term issues due to radiation exposure (Lewis, n.d.). The distance from Earth will also require psychological training prior to launch, although certain problems that would arise from Mars missions can be mitigated as near instantaneous communication with family and friends on Earth will be routine. Furthermore, contact with Earth-based ground stations will allow for crew members to be psychologically analyzed on scheduled times in order to prevent any issues from arising. Crew members will be able to find psychological benefits through distractions in later stages of lunar base construction as well, since members will be heavily involved in experiments for Earth, such as the construction of radio telescopes on the far side of the moon and moon jaunts using pressurized moon rovers. The crew will also take pride in helping humanity cement itself in space and assisting their nations as crew members will be selected from various countries, including those not necessarily allied with the United States, in order to better relations and set an expectation for camaraderie and international cooperation in space to keep space clean of politicization.

Creating a permanent lunar base will become a historic and unprecedented event in the timeline of humanity, marking the entrance of humanity onto the extraterrestrial scene. With the enormous significance of this primary lunar base, it is imperative that the obstacles facing future exploration of deep space is countered and tested, showing the inventiveness and ability to solve engineering problems necessary for exploring Mars. Aside from paving a pathway to Mars, the experimentation and opportunities for manufacturing and resource collection on the Moon will create boundless benefits for humanity as a whole as people everywhere will be able to gain access to cheaper energy and manufactured products that would be impossible to make on Earth. The proposed lunar base’s design and focus on increasing the safety of astronauts and creating access to space for more people will offer compounding returns, ensuring that the problems of resource scarcity facing the world today will become a thing of the past and that the ability to continue exploring will be safe and easy.

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