Project Artemis

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Abstract

Project Artemis is a multi-stage program led by NASA to put a man and a woman on the Moon by 2024 and have a permanent base by 2028. Located on the edge of Shackleton Crater on the south pole of the Moon, the graphics attached at the bottom of the document depict Artemis Base in the year 2050, by which point a habitat, the Domes, a mining facility and refining factory, spaceport, and nuclear fusion reactor have been built to sustain life. Driven by a fleet of autonomous robots, the strip mine produces regolith and ice that is processed into water, oxygen, hydrogen, rare metals, and Helium-3 that is used in nuclear fusion. Six astronauts, a Commander, SysOp, Botanist, Medic, Scientist, and Engineer, will live on the Base for a year at a time before returning to Earth and letting a new crew take over. They will oversee the function of the base and perform research to learn more about the Moon. The base will be primarily funded by the U.S government, but private companies and other nations are contributing to claim a stake in the shaping of Artemis Base. NASA hopes that such a venture will open the door to further space exploration by giving them easier access to Mars and beyond and rekindling public interest.

Keywords: Project Artemis, NASA, Moon, Shackleton Crater, Domes, mining facility, refining factory, spaceport, nuclear fusion reactor, autonomous robots, Helium-3.

Project Artemis

NASA’s Project Artemis is a multi-stage program to put one man and one woman on the Moon by 2024, establish a permanent base of operation by 2028, and build an orbiting station around the Moon, named Gateway (Artemis, n.d). What will follow is still to be determined, but, over the next 40 years, NASA hopes to establish a fully functional base that is capable of taking full advantage of the Moon’s resources, advance our understanding of the Moon’s properties, and provide NASA with a jump-off point to more efficiently get to Mars and beyond. NASA expects that the base will be able to fulfill these by 2040. The location chosen for Artemis Base is the edge of the Shackleton Crater. Located at the lunar South Pole, it receives year-round sunlight and line of sight to Earth for easy communication. The graphics attached to this document illustrate the base as what is expected to be 2050, complete with the future technology we expect to incorporate at Artemis base to increase productivity and improve quality of life for the astronauts, including a fusion reactor to power the base, fully autonomous machinery, and other technology about which NASA is hopeful. While the first humans to walk on the Moon in 52 years will only come in a pair of two, NASA expects that by 2060 Artemis base will host six astronauts at a time for a year. A lunar base will help rekindle interest in space exploration, give us a better understanding of our solar system, and allow us to look beyond the Moon to Mars.

# Timeline

With Artemis projected to be established by 2028, NASA expects to develop the base to accommodate more astronauts and begin expanding commercial interests, like mining Helium-3, water, and rare metals, as they move into the 2030s. At this point, NASA will use the Gateway station to begin sending SLS rockets to Mars. Artemis base can help with that by producing rocket fuel by separating the water that is mined from Shackleton Crater. Artemis base should be mass-producing Helium-3, water, and rare metals by 2040. They can be used at the base or sent back to Earth from the spaceport on an unmanned cargo rocket and then sold. By 2050, Artemis Base should be a fully-functional entity. At this point, expansion to accommodate private sector interests is very feasible. Space tourism, private mining companies, research entities, and various other pursuits will want to plant their flag in the lunar regolith.

# Location

Choosing the location of the next lunar base is a hotly debated topic. The Apollo missions landed in the Sea of Tranquility, a relatively flat, easy target to land at. With no intention to stay for more than a few hours, there was no pressure to land somewhere rich in resources or that could sustain a base for long. For Project Artemis, all these factors had to be considered. In the end, the location chosen was Shackleton Crater. Located at the southern pole of the Moon, Shackleton Crater is unique in that, on the rim of the crater, you receive perpetual sunlight (3D-printing a lunar base, 2014). This means that solar panels can be used constantly without the immediate need for alternative energy solutions during the 13 day long lunar nights. The surface of Shackleton Crater is also believed to be as much as 22% ice that the mining robots could harvest and turn into liquid water for the astronauts, the hydroponic farm, or to split into hydrogen and oxygen for rocket fuel (Detailed Characterization of Shackleton Crater, n.d).

# Operational Concepts

By 2050, the base will comprise of four parts: The Domes, the spaceport, the strip-mining facility, and the fusion reactor. Initially, autonomous robots will be sent to the Artemis base sight to build the Domes. Using a technology pioneered by the European Space Agency (ESA), they will use an inflatable dome as structural support as they use regolith to make a concrete-like printing material (3D-printing a lunar base, 2014). They will use a pattern like the anatomy of avian bones to print a light, yet strong outer shell over the inflated base to protect it against radiation, small projectiles, and extreme temperature changes. The container that The Dome came in will serve as the airlock to individual Domes before they are connected to form the passages between Domes. By the time the first pair of astronauts land on the Moon, the Domes will be assembled and ready for use. At first, the primary source of energy will be solar panels that take advantage of Shackleton Crater’s unique position. As technology develops and the electrical need of the base increases, a fusion reactor will be built on the Moon to take advantage of the easy supply of Helium-3. One is in development right now by Lockheed Martin’s Skunk Works that is ten feet by 7 feet, or small enough to fit in a pickup truck. It is estimated that, when it reaches maximum capacity, it will be able to provide energy for 100,000 people (Compact Fusion, n.d). Technology like this is quickly developing and should be available in a few decades. The solar panels will remain as a source of back-up power, and batteries will be stored in the reactor dome to store energy for similar possible problems. Next will be the strip-mining facility. To begin harvesting the water, oxygen, Helium-3, and rare metals, the robots must start digging. Several mining pits will begin to form inside Shackleton Crater and on the rim as the autonomous robots start collecting regolith. The unprocessed regolith will be transported to the refinery where it can be separated into the valuable resources the astronauts need to survive, or for them to send back to Earth to be sold. The final component is the spaceport. Rockets will be landing at Artemis base to bring resources, robots, equipment, and new astronauts. They need a permanent place to land to increase efficiency, so the robots will flatten out an area of regolith away from the base where they can lay concrete and begin making landing pads for rockets as well as a launch tower for rockets to return to Earth, laden with resources and astronauts at the end of their shift, or to fly on to Mars and beyond with the next great pioneers. The spaceport will have a large warehouse for the storage of the processed products from the refinement facility and any imports that rockets bring to Artemis Base before they are distributed wherever they are needed. Once these modules are completed, Artemis Base can be fully functional and serve as our first extraterrestrial colony.

# Personnel

The most critical component of Artemis Base is the astronauts. While only 2 astronauts will fly to the Moon on Artemis III, Artemis Base will be the home of six astronauts at a time by 2040. There will be set roles while at Artemis Base; the first is the Commander. The Commander is the leader of Artemis Base during their shift. All other personnel answers to the Commander. They oversee all activities in the control center, make sure that Artemis Base is on schedule and working normally, and manage the day-to-day activities of the crew. They are required to have basic training for all other required positions at Artemis Base. During the journey to Artemis Base, they will serve as the pilot if the autonomous systems fail. As such, there is an emphasis on picking former military pilots who have experience with aerial vehicles and leading others while under duress. They are expected to be level-headed, decisive, intelligent, and natural leaders. They are under constant pressure to ensure the safety of their crew and Artemis Base. The System Operator (SysOp) is second in command. Their specialty is computer systems. They use the programs at the Base to monitor communication systems, command the fleet of autonomous robots, and streamline the Base’s day-to-day operations. They are also trained to be secondary reactor technicians. The selection process puts an emphasis on computer science (or similar) degrees as well as extensive experience in the field. High intelligence is key as well as an exceptional ability to balance multiple tasks and quickly process new information. If the Commander is unable to perform their duty, whether it be simply because they are off their shift or because they are physically unfit to work, the SysOp is the first in line to succeed them as the temporary Commander. The third crewmember is the scientist. The scientist is responsible for carrying out the experiments that NASA wants information on. They will process data collected from sensors across the Moon to help better understand our celestial companion. Their preferred majors include astrophysics, chemistry, geology, or other prevalent science degree. Higher levels of education are preferred. The major personality trait is high intelligence. NASA needs its scientist to be on the cutting edge of lunar exploration and research. Not anyone can fill that position. The fourth crewmember in line is the botanist. The botanist oversees the hydroponic farm in the Domes. They perform experiments to test the viability of various crops and conditions to find the most effective and efficient crops to feed six hungry astronauts with. NASA is looking for people with notable careers in the biology or ecology field and degrees in plant science or a similar major. The botanist is also trained as a secondary medic as a precautionary redundancy. The fifth member of the crew is the primary medic. They are trained to perform advanced medical treatments in 1/6g and to monitor and record the crew’s health. They are required to have an MD and an advanced understanding of the medical procedures necessary for specific wounds that astronauts, specifically, might encounter as well as an extensive career background. Since they had an advanced understanding of the human body and won’t be treating someone around the clock, they are also trained to assist the botanist with their crop production and experimentation. As they will be required to do psychological examinations on each crew member every week, they will be the primary emotional conduit for the crew. They will be trained to work as a therapist and psychologist for the crew to help cope with the psychological effect of living on the Moon, but they should show signs of being empathetic, understanding, supportive, and analytical. The sixth member of the crew is the engineer. The engineer is in charge of maintaining the various systems across the Base. They must have a degree in electrical engineering, (once the fusion reactor is integrated) nuclear engineering, mechanical engineering, software engineering, or another related discipline. They must be quick learners, have a knack for machinery, and be able to grasp the big picture and the tiny details side-by-side. Their preferred occupations include high-ranking engineers, project managers, and solution designers. They must be prepared for a million possible problems and be able to solve a million more on the fly. They maintain the electrical grid that powers the Base, the robotic systems, the refinery, the spaceport, and the Domes. They will be taught about the various systems and their internal parts. If something breaks, they are who you call. Because their roles go together, the engineer’s secondary role is the backup SysOp. Each role has a primary and secondary crewmember assigned to them so that, if someone cannot complete their job because they are sleeping, working out, or they are physically unfit to work, nothing goes unchecked. All astronauts are limited to one year at Artemis Base every three years. This minimizes muscle atrophy, radiation exposure, and other long-term medical problems that astronauts are prone to. The Domes are protected, but there is only so much they can do to avoid radiation. Once back on Earth, they can help train new astronauts and learn about newer technology that is being incorporated in Artemis Base. After two years, they can rejoin the year-long training for returning crewmembers. New astronauts will have to undergo a two-year training program (Commanders have an extra year of training to ensure that they are the best candidates to lead Artemis Base) to prepare them for daily life on the moon. NASA disregards country and gender when selecting candidates. If they can perform what NASA expects its astronauts to, they are eligible. Age is considered when looking at applicants. While experience is a large factor, with age comes medical problems. If a candidate is above the age of roughly 45, their future health might play a part in their selection. It isn’t a hard filter, but it may be a damper if compared to someone with the same qualifications who is 35. As previously mentioned, new astronauts are picked based on their area of expertise, health, and work experience. Different roles require different skills, but NASA expects all their astronauts to be in near-perfect health, intelligent, good at working with others, calm under stressful situations, and good at learning new things. Living on the Moon is no easy task. It is a harsh environment that will kill someone in a million different ways. NASA needs the best of the best to make sure Project Artemis is a success.

# Activities

The Domes will be supported by a complex life support system akin to the one aboard the ISS. Ice will be mined from Shackleton Crater to provide liquid water for the astronauts. Oxygen mined from the regolith and split from water molecules will be filtered through the Domes. The CO2 the astronauts exhale will be captured in CO2 scrubbers and then used in the hydroponics farm to help the plants grow and produce ATP and oxygen. The Domes are outfitted with various sensors to help regulate that temperature, humidity, oxygen level, simulated air pressure, and various other factors that go into keeping six humans alive. The scientist’s main objective will be to study the lunar surface. They will use an assortment of equipment and sensors to study the composition of the regolith, the quantity of various elements and resources on the surface, what lies deeper in the Moon’s interior, and other qualities that will help us better understand the Moon.

While the idea of putting telescopes and other equipment on the moon to search the night sky is enticing, the drawbacks mean that it is not a cost-effective solution and essentially tries to fill the role of other telescopes already in operation; the main ones being cost, the position of the moon, and moonquakes (Siegel, 2018). The R&D and shipping cost of trying to put a telescope on the Moon that is big enough to take detailed readings would be astronomical compared to Earth-based telescopes and satellites. On top of that, the Earth produces a lot of EM wave interference that would severely limit the potential of a Moon-based telescope to produce hyper-detailed data (Siegel, 2018). It could be put on the dark side of the moon to avoid the interference, but then upload/download speed would be severely limited, and a relay station would be needed on the relative horizon to bounce the signal around the Moon. Furthermore, the Earth’s tidal-lock on the Moon produces severe moonquakes (Siegel, 2018). These have the potential to damage the highly sensitive instruments in the telescope.

Most of Artemis Base’s manufacturing comes from the refinery. It will produce water, oxygen, rocket fuel, Helium-3, and various crucial resources for the construction of the base from the regolith and ice in Shackleton Crater. The cost of shipping most of these products far outweighs their value, making it not worth selling, except for Helium-3. The Moon is the only place that Helium-3 is currently accessible from. Earth’s magnetic field prevented the solar winds from bringing Helium-3 to Earth, but, as the Moon has no magnetic field or atmosphere, its regolith is rich with it (Mining Rare Mineral From The Moon, 2017). The concentration of Helium-3 is relatively low at 20-30 ppb, so you would have to dig a large quantity of regolith to produce any noticeable result. “A patch of lunar surface roughly three-quarters of a square mile to a depth of about 9 ft. should yield about 220 pounds of helium-3--enough to power a city the size of Dallas or Detroit for a year.” (Mining Rare Mineral From The Moon, 2017). Despite these dubious figures, the price of Helium-3 makes it worthwhile; at $40,000 an ounce, it’s 25 times as expensive as gold. 220 pounds of it would sell for $141 million (Mining Rare Mineral From The Moon, 2017).

Once fusion reactors become a reality, Helium-3 will help power the very place it was harvested from. The Artemis Fusion Reactor will power Artemis Base indefinitely as it continues to grow, and more people come to the Moon to find their fortune.

Communication with Earth will be achieved via an array of satellite dishes that broadcast information to satellite arrays on Earth. The travel time of the data from the Moon to Earth is 1.3 seconds, so communications will be almost instant (Skorucak, n.d).

Astronauts will get between modules using rovers, like the Apollo crew. They have been updated to accommodate frequent use. They now run on rechargeable lithium-ion batteries, are made of more durable materials, and can accommodate 3 astronauts at a time along with their cargo. They can be outfitted with long-range modules that hold a temporary inflatable shelter, not unlike what the Domes are designed to do, several meals, a repair kit, solar panels to charge the rover, a communication satellite dish, and several tanks of oxygen and water for use on long-range exploration missions. Every astronaut is trained to operate the rovers.

NASA understands what psychological effects stem from working on the most desolate place inhabited by humans can have on a person’s mentality, let alone working every day, so they incorporated a social area where crewmembers can relax, talk, play games, read, or other leisurely activities to unwind after a long day. Crewmembers can also create the first-ever game of soccer, football, or baseball on the Moon, albeit with balls that would not explode in the vacuum of space. The lunar Olympics would be a rather amusing test of lunar endurance while wearing bulky spacesuits, a great way to further develop unity, and give the crew a day off.

# Governance

Project Artemis is a NASA-run program with help from international allies and commercial interests. Anyone from any country can be selected to become an astronaut for Project Artemis. The mission will be managed by the mission control center at the Johnson Space Center in Houston, Texas. Project Artemis’ initial funding will be provided mainly by the US government, but also by private companies and international allies looking to use Project Artemis’ unique position to further their purposes. Most of Artemis Base’s funding after it has been established will be through the production and sale of Helium-3. In the later stages of Artemis Base, there will be an exponential increase in private sector interest and funding to get them to the Moon. The major law dictating NASA, or any other governing body, in space is the Outer Space Treaty of 1967. It dictates that any exploration of space must be peaceful, no nation can claim a celestial body, and nobody can harbor weapons in space, like nuclear warheads. As private sector companies become more interested in mining the moon, land disputes and mining licenses will become a heated debate and more laws are sure to be passed in the future.

Project Artemis’ main goal is to provide a gateway to space exploration (hence the name of the space station). By colonizing the Moon, NASA is opening the door to Mars and beyond. What NASA learns on the Moon will be critical to how we approach future colonization attempts. It will also present NASA with a crucial hub for future commerce and tourism. The Moon is the key to our future in space. The extraction of Helium-3 will power the future cities of the world. The rocket fuel produced on the edge of Shackleton Crater will push rockets to Mars for centuries to come. Project Artemis is the first foothold for NASA to climb to colonize the solar system. When the first man and woman step out of their lander and gaze upon the lunar surface up close for the first time in 52 years, they will begin an exponential movement of humans into space. Colonizing our neighboring planets and beyond is the key to the future of humanity. In millions of years, when the sun becomes a red giant and consumes Earth in its fiery atmosphere, human-kind will not die out. They will exist across the universe in the most distant galaxies and solar systems and it all began with Project Artemis.

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