

Lunar Base Design

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This technical report outlines the design of a permanent lunar base that is meant to support and allow for long-term human presence on the Moon, but also serve as a means to advance scientific research, utilize resources, and prepare for future missions to Mars and beyond. With a threefold approach, the purpose of this lunar base is to allow for continuous human habitation, to conduct both scientific and technological research that can only be done in the lunar environment, and to demonstrate the usage of sustainable systems such as closed-loop life support. In order to meet these goals, the base design integrates habitats, laboratories, power systems, manufacturing and mining facilities, transportation infrastructure, and communication systems. This report presents a detailed timeline of the mission, the selected lunar location and necessary environmental adaptations, operational concepts and technologies, personnel structure, supporting activities, governance framework, and a concluding assessment of the significance of the mission for the long-term.

Timeline

The mission architecture follows a phased approach that is justified as a means to make sure that systems can be gradually tested and risks can be reduced before actual long-term human habitation begins. The first phase involves robotic precursor missions launching between 2028 and 2031. The intent behind these uncrewed missions is to focus on the preparation of the site and data collection while also delivering important infrastructure. For example, this infrastructure includes solar power arrays, communication relay satellites, robotic construction equipment, inflatable habitat shells, and core life support hardware. By using multiple landers with solely cargo, redundancy is created, and it helps ensure that failing a single launch doesn't compromise the whole mission.

The construction of the lunar base itself starts in the year 2032, after robotic systems ensure stability in terms of power, communications, and surface. Next, the first human crew arrives in July 2034 aboard a crewed lunar lander, which consists of four astronauts assigned to a six-month commissioning mission instead of a permanent settlement. They come with supplies already being there, such as food, medical equipment, spare parts, oxygen reserves, and backup power systems. By December of 2034, habitats are covered with regolith for radiation shielding and temperature control, and by March of 2035, oxygen extraction and water processing systems are activated to slowly reduce dependence on Earth. Then, additional laboratory and greenhouse modules are constructed by mid-2036, and the base becomes fully operational in January 2037. When it's fully operational, it will be able to support continuous crew rotations of between six and eight astronauts with partial self-sufficiency in areas like power, oxygen, and water. In regard to the future, the base is designed to slowly expand to support larger crews, increased manufacturing, and future deep-space missions.

Figure 1

Mission Timeline

Date	Event
2028-2031	Robotic precursor mission delivers power, communications, and construction systems
2032	Lunar base construction begins
July 2034	First crew of four arrives for commissioning mission
2034-2036	Habitat shielding, life support activation, and facility expansion
January 2037	Base becomes fully operational (6-8 crew)
Post-2037	Crew shifts every six months, base expansion,

	and support for future deep-space missions
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Location

The lunar base is located near the south pole of the Moon, specifically near the rim of the Shackleton Crater at approximately 89°S 0°E. This site was selected because of its generally stable terrain alongside its continuous solar illumination and proximity to permanently shadowed regions of the Moon that contain water ice deposits (Johnson, 2022). However, there are still a lot of extreme conditions that need careful adaptation.

The one-sixth gravity of the Moon results in muscle and bone loss, which is addressed by daily resistance exercise and continuous monitoring from a medical perspective. Due to the vacuum environment of the Moon, all habitats and laboratories are fully sealed and pressurized. Lunar dust and regolith, being abrasive and electrostatically charged, are controlled by using surface coatings that are resistant to dust, filtered airlocks, and specialized exterior suits. The potential exposure to solar wind and cosmic radiation is reduced by covering habitats with about two to three meters of compacted regolith, alongside having shielded storm shelters as well. In order to account for extreme variations in temperature that range from about -173°C at night to 127°C during the day, thermal insulation is used with active heating and cooling systems in place (Barry, 2025). Lastly, the fourteen-day lunar day-night cycle is addressed by having the base in the region with near-continuous sunlight, which helps to limit dependence on long-term energy storage.

Figure 2

Shackleton Crater (Dunbar, 2023)



Operational Concepts

Habitation

The habitation system features modular living buildings that are made for long-term use by the crew. These habitat modules are connected and reinforced by having rigid supports. They are then covered with compacted lunar regolith to protect against conditions like radiation, extreme temperatures, and micrometeoroids (Rafferty, 2018). There are also built-in life support systems in order to make sure that air pressure, oxygen levels, temperature, and humidity are controlled to maintain safe and stable living conditions.

Facilities

The base includes several facilities that help with science research, manufacturing, and sustainability over the long-term. Laboratories are presented and used for lunar geology, materials science, and biological research. There is a small astronomical observatory, placed away from the main habitat lighting, that allows for clear observation of deep space. Industrial

systems help extract oxygen from lunar regolith but also help process water ice into drinking water and rocket propellant. Greenhouses use hydroponic growing systems, and LED lighting is involved with this in order for there to be food and for carbon dioxide to be recycled, reducing the need for supplies from Earth (Kaiser, 2024).

Transportation and Equipment

Surface operations are dependent on the usage of specialized machines, equipment, and rovers. For example, robotic machines help handle excavation, transportation of regolith, and construction to ensure that the exposure of the crew to hazardous conditions is limited. Roads made from hardened regolith connect different areas of the base and allow for safe travel by rovers. Pressurized rovers are present to help transport crew and cargo across the lunar surface, alongside on-site manufacturing equipment like 3D printers, helping replace tools and replacement parts when needed (Ulgade, 2025).

Personnel

As an international mission, the lunar base crew is made up of astronauts from the United States, Europe, and other partner nations, helping aim for gender diversity and a balanced skill set among the crew. The age range of the crew members is from 30 to 55 years old. Astronauts are selected through a holistic review of physical fitness, technical expertise, and simulated tests to determine the ability of potential crew members to work in confined and high-risk environments (Logsdon, 2026). This demographic balance helps support reliable long-duration operations.

Crew Size and Selection Process

Each mission includes six to eight astronauts. These astronauts rotate every six to nine months. Astronauts are required to follow a daily structure that involves specific items related to

system maintenance, scientific research, surface operations, physical exercise, and rest periods. All crew members are cross-trained, which helps to give the flexibility for each astronaut to perform multiple roles. This includes engineering maintenance, scientific data collection, medical support, and emergency response, so operations can still continue even if one astronaut can't work, and allows for astronauts to be assigned to specific missions based on such factors (Logsdon, 2026).

Medical Concerns and Psychological Needs

The main medical concerns relating to this entire concept include exposure to radiation, bone density loss, muscle atrophy, and immune system changes that are a result of long-term exposure to low gravity. In order to combat these risks, continuous health monitoring is essential alongside daily resistance exercise and preventative medical countermeasures. With regards to psychological needs, they are addressed by having predictable daily routines, private living quarters for each of the astronauts, regular communication with Earth, and access to recreational and fitness activities through virtual reality, which can help with reducing stress and supporting mental well-being.

Activities and Governance

Daily operations at the lunar base mainly involve keeping the station functional and productive. For crew members, this means maintaining life support and power systems, conducting scientific lunar geology research and astronomical observations, and testing manufacturing methods that use lunar regolith. There is still continuous communication with Earth to support data transfers and mission planning, while rovers are used to travel the surface, explore, and move equipment. Although it's not the focus of the mission, there will be specific allotted, scheduled recreational time embedded into schedules to support crew mental health, as

these are long-duration stays. The base operates as an international program that is managed jointly by participating space agencies, and funding is provided by member governments and research partners. All activities are conducted in accordance with international space law, including the Outer Space Treaty (Britannica Editors, 2024).

Conclusion

This lunar base design provides a realistic and sustainable plan for maintaining a permanent human presence on the Moon. By using a construction approach that proceeds in phases, adapting to the lunar environment, and relying on technologies that have been proven, the base can safely support long-term scientific research and provide resources for use. The construction of the base, along with consideration of the crew, given their workload, activities, environment, and governance, is meticulously planned to allow for further expansion and increase manufacturing capabilities. Operating this base would give astronauts valuable experience living and working beyond Earth, and in regard to future implications, this would be a strong step for preparing future human missions to Mars and deeper space exploration through actual settlement experience.

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