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# Essential Moon: A framework for permanent lunar development


## Abstract

The Essential Moon presents a comprehensive and visionary framework for establishing a permanent human and robotic presence on the Moon as the foundation for humanity's expansion into the Solar System. Moving beyond the symbolic achievements of Apollo and the complexity of current proposals like Artemis, this concept advocates a new paradigm based on simplicity, modularity, and long term sustainability.

At the core of this vision lies the Essential Moon Mission Architecture, centered on a fully reusable Cruiser–Feeder Transportation System and a family of standardized modular Containers. This system enables continuous, cost -effective operations between Earth, lunar orbit, and the Moon's surface creating an adaptable logistics network without reliance on heavy launch infrastructure.

The proposed development unfolds in phases. The first stage focuses on robotic missions that establish communications, deploy solar and power networks, and prepare the lunar site using autonomous rovers and AI systems. Once life -support and energy systems are operational, the first human crew arrives to activate the outpost, initiate mining and in -situ resource utilization, and experiment with local construction materials to achieve long term self-sufficiency.

Every step is guided by a unified Master Plan, ensuring that individual missions contribute to a coherent, expanding lunar infrastructure. The Moon becomes not an endpoint but an operational platform —a base for research, manufacturing, and interplanetary logistics. The Essential Moon project defines a realistic path toward a sustainable, economically viable, and permanent human civilization beyond Earth.


**Keywords:** moon, earth, solar system, lunar development

Volume 9 Issue 4 - 2025

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**Received:** October 24, 2025 | **Published:** November 10, 2025

## Introduction

Humanity stands once again on the threshold of a new era in space. Following the triumphs of the Apollo missions, the engineering milestones of the Space Shuttle program, the international cooperation of the ISS, and the pioneering successes of inter planetary probes, we are now poised to transition from exploration to establishment. The age of heroic first steps is giving way to the age of sustainable presence. The Moon, once a distant symbol of ambition, is now the logical foundation for humanity's expansion into the Solar System.

Yet, despite decades of progress, our trajectory has faltered. The recent debates around NASA's Artemis program, and the criticism it has received for being overly complex and fragmented, reveal a deeper problem: a lack of clarity in purpose and method. Nearly sixty years after Apollo, humanity has not yet demonstrated the ability or the collective will —to return to the Moon with permanence and purpose. We risk repeating the mistakes of the past: monumental achievements without continuity, innovation without integration.

To move forward, we must adopt a new philosophy of space development one rooted in simplicity, modularity, and sustainability. The Moon must not be viewed as a destination but as an essential platform a permanent base of operations that enables exploration, industry, and expansion across the Solar System. Every mission should serve as a building block within a coherent, evolving master plan. Vehicles must be fully reusable, logistics streamlined, and costs minimized through automation, in -situ resource utilization, and intelligent system design.

This new approach demands a fusion of visionary thinking and disciplined engineering. Instead of complex, one-off missions, we need an incremental, scalable architecture a lunar infrastructure capable of supporting research, habitation, manufacturing, and energy production. Each component rovers, habitats, power systems, and launch vehicles should integrate seamlessly into a self-expanding ecosystem.

The Essential Moon concept envisions the lunar surface not as a distant outpost but as humanity's second home a testing ground for technologies and societies that will one day reach Mars and beyond. It is where we will learn to live off world, extract and refine resources, build with local materials, and establish the first autonomous industrial and scientific bases beyond Earth.

If the twenty-first century is to be defined by humanity's expansion into space, the Moon will be its cornerstone. The nations and organizations that embrace this new paradigm —focused on efficiency, permanence, and collaboration —will lead the next great chapter of human civilization. Without such vision, we risk standing still while others take the leap.

## The essential moon

Phase 2 of space development, starting with the return to the Moon missions, marks a transformative milestone in humanity's evolution from an Earth -bound civilization to a truly spacefaring species. At its core lies the Essential Moon Mission Architecture — a visionary yet pragmatic framework designed to:

a. Create a permanent totally reusable, Earth Moon, space transportation system
b. Enable permanent lunar operations, with lunar bases to become settlements

c. Develop a self-sufficient lunar technology to satisfy all requirements minimizing dependence from Earth

d. Develop a sustainable lunar economy,

e. Test and prepare for the first crewed expeditions to -Mars and beyond

The Essential Moon project envisions the creation of a permanent, scalable, and self -sustaining lunar presence, built progressively through clearly defined phases. Its architecture is designed for simplicity, modularity, and reuse—favoring technologies that already exist or can be derived from proven Earth-orbital systems. The entire program is conceived not as a one -time expedition, but as, the foundation of a continuous human –robotic civilization extending into space.

## The cruiser–feeder space transportation system

At the foundation of a continuous human robotic civilization extending into space lies the Cruiser Feeder Transportation System an entirely reusable, modular, and cost effective solution designed to revolutionize access to orbit, the Moon, and beyond. This system is composed of three core elements: the Cruiser, the Feeder and a standardized family of Containers. Together, they form a flexible and scalable architecture capable of supporting sustained space operations and long term expansion.

**The Cruiser,** functions as an interplanetary ferry, operating in Earth or lunar orbit, or cycling between planets and moons. It provides propulsion, power generation, and life -support for both crewed and autonomous missions. The Cruiser's structure is ring -shaped, housing its engines and fuel tanks within the ring itself, while central modules host operational functions such as the Node Module for docking and logistics, and optional Habitat Modules for crew or settlers. Its design allows for expansion both axially and vertically, enabling its evolution into an artificial -gravity spacecraft suitable for future Martian missions. Cruisers can be refueled by feeders equipped with fuel tank as containers at any time when needed.

**The Feeder**, similar in ring configuration to the Cruiser, serves as a reusable shuttle operating between planetary surfaces, orbiting Cruisers, and space stations. Its circular frame enables vertical takeoff and landing, integrating propulsion systems, fuel tanks, avionics, and landing gear within a compact, easily serviceable structure. This design minimizes the need for complex ground infrastructure, ensuring rapid turnaround between flights. Its shape allows instant accessibility to planetary surface without the need of ladders, stairs or mechanical elevators.

**The Containers**, standardized at six meters in diameter, can be adapted for cargo, habitation, or specialized tasks. Crewed versions permit flexible mission configurations for both human and robotic operations. Positioned at the center of the ring shaped Feeders, these containers allow for effortless loading and unloading, providing immediate ground -level access without the need for stairs, ladders, or elevators simplifying logistics and enhancing operational safety.

Together, these components create a continuous, modular logistics chain linking surface bases, orbiting Cruisers, and space stations. By eliminating dependence on traditional launch complexes and heavy ground facilities, this system introduces Vertiport-style hubs compact operational centers equipped with cranes, maintenance hangars, and storage bays instead of conventional spaceports. Vertiports can be established in remote or isolated areas, preventing interference with conventional air traffic while supporting frequent, reliable operations.

This architecture streamlines procedures, lowers operational costs, and drastically increases flight frequency—key enablers for sustained industrial, scientific, and settlement activities on the Moon, Mars, and throughout the Solar System (Figure 1) (Figure 2).

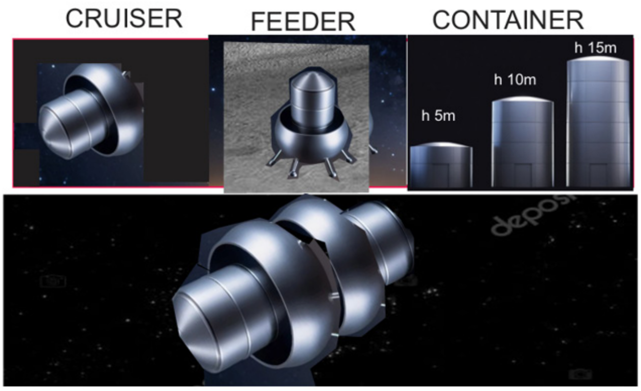


**Figure 1** Cruiser/feeder system components.

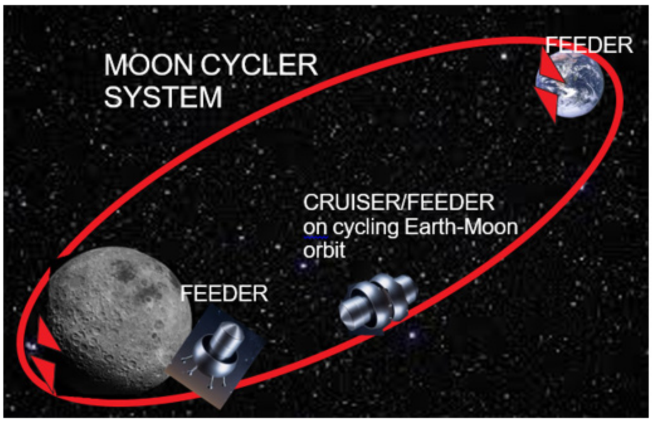


**Figure 2** Cruiser-feeder on Earth-Moon cycling orbit.

Beyond technology, Phase 2 embodies a broader transition from exploration to occupation, from isolated missions to permanent habitation, and from national co to cooperative expansion. Its success will rely on parallel advancements in roboticist resource utilization, and close dloop life-support systems—all essential for auto and long-term viability in extraterrestrial environments. Initiatives will not arise f single breakthrough but from the coordinated progress of many sec to research institutions, private industries, defense agencies, and international alliances each contributing to a shared vision. Much like the synergy that fueled the Cold War s this distributed innovation will converge toward a unified goal: the establishment permanent human foothold in space and, ultimately, the development interstellar capabilities. Phase 2 thus represents the first true step in transforming humanity's in the Solar System from temporary exploration enduring civilization.

## Advantages of the ring system

Compared to both the SpaceX Starship concept and the Blue Origin proposal, the Ring System offers several significant advantages:

**a. Compact dimensions**

The overall structure is smaller and more space -efficient, allowing for easier deployment, transport, and integration with existing infrastructure.

**Citation:** Gaviraghi G. Essential Moon: A framework for permanent lunar development. *Aeron Aero Open Access J.* 2025;9(4):184‒191.
DOI: 10.15406/aaoaj.2025.09.00237

**b. Operational simplicity and full self -sufficiency**

The system is designed to be fully autonomous, minimizing the need for complex support systems or ground crews. Once operational, it can function independently with minimal external input.

**c. Direct ground-to-space and return capability**

The Ring System enables direct transit between the ground and orbital levels without intermediate stages, boosters, or detachable modules. This ensures faster turnaround and reduced complexity.

**d. Seamless ground access**

The design allows direct exit to the planetary surface —no stairs, ladders, or mechanical boarding equipment required —improving both safety and efficiency for crew and cargo transfer.

**e. Simplified refueling**

Refueling can be performed quickly using modular fuel tank containers, reducing downtime and simplifying maintenance logistics.

**f. Expandable "Cruiser" capability**

The core system can be expanded into a larger cruiser or transport configuration, supporting long-range operations or interplanetary missions.

**g. Modular container architecture**

The use of standardized, interchangeable modules enables rapid configuration for cargo, habitation, or research purposes. This flexibility supports a wide range of mission profiles.

**h. Complete reusability**

All components of the system are designed for 100% reuse, eliminating expendable parts and drastically reducing long -term costs.

**i. Minimal operational costs**

Due to its reusable nature, autonomous functions, and low maintenance requirements, the Ring System achieves the lowest cost per launch and operation cycle among comparable solutions (Figures 3–5).

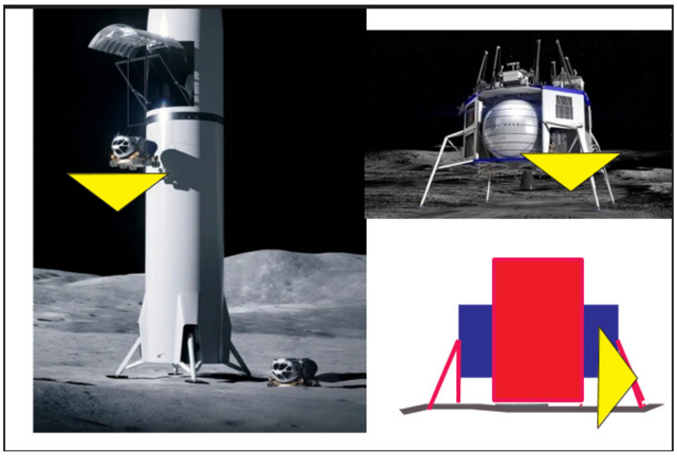

**Figure 3** Exit in surface.

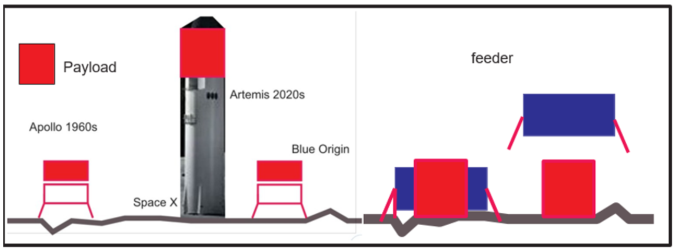


**Figure 4** Payload at exit.

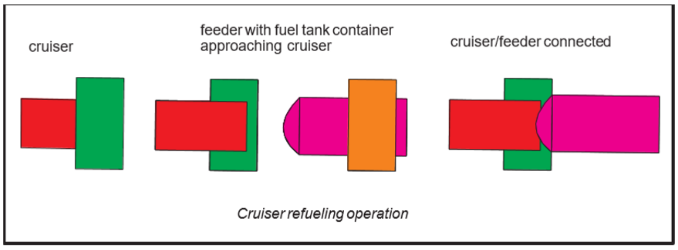


**Figure 5** Cruiser refueling operation.

**j. Minimal development costs**

Estimating the Ring development costs at 5B $ , considering that similar technologies have been applied to the Apollo lunar module or proposed by Blue Origin and a total schedule of 3 years to be operational a complete lunar mission will never exceed the 50 million $ mark, including equipped containers and manned capabilities.

## Economic projection

One of the main advantages of the Ring system is estimated costs since we are at an order of magnitude more economic than Artemis.

## Let's analyze details

The NASA Office of Inspector General (OIG) projects that from Fiscal Year (FY) 2012 through FY2025, the Artemis Program will cost approximately US $93 billion. The first four launches of the Space Launch System (SLS) and Orion spacecraft are estimated to cost about US $4.1 billion each (production and operations), excluding most of the earlier development costs. These figures cover activities only through 2025; future phases and complete infrastructure development are not included in that estimate.

**Comparative cost analysis: Artemis vs. feeder ring system**

In comparison to NASA's Artemis architecture, the proposed Feeder Ring System presents substantially lower development and operational costs.

**Feeder / Ring vehicle development**

1) **Estimated development cost:** US $5 billion (Based on heritage technologies used in the Apollo Lunar Module and the Blue Origin Artemis lander proposal.)
2) **Development timeline:** Approximately 3 years
3) **Unit production cost:** Around US $500 million per vehicle

**Phase 1 – Unmanned preparation**

I. **Planned utilization:** four vehicles

One Cruiser

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Three Feeders equipped with modular containers (unloaded)

II. **Total Phase 1 cost:** Approximately US $2.5 billion or 500M if all vehicls are reutilized (Includes reusable vehicles and container systems that can be reconfigured for future missions.)

**Phase 2 – First manned mission**

Estimated cost: US $1 billion

(Includes one manned vehicle and a habitation module.)

## Operational advantages and cost efficiency

While these costs are two order of magnitude lower than NASA's projected expenditures, it is important to emphasize that the Feeder Ring System is designed to be fully reusable.

Once the system becomes operational, a complete Earth –Moon mission could be conducted for less than US $10 million per flight, enabling sustained lunar development and transforming Moon operations into a commercially viable, continuous business activity.

## Return to the moon

This activity should be performed as part of a Master Plan and not as a dead end mission like the proposed Artemis with an exorbitant cost of 4B$ per launch.

We can describe such Master Plan by its phases

### Phase I Robotic outpost

Once the transportation system, the feeder and an embryonic cruiser could be ready, the first activities should be to send robotic rovers and AI to prepare the site for the outpost construction. If urgency is the issue it could be possible to send the containers by Falcon 9 launchers fully available directly to the Moon selected site. The sequence will be as follows:

### Robotic outpost and first lunar base development concept

1) Purpose establishing a permanent, self -sustaining human presence on the Moon requires a carefully staged approach. A robotic outpost is the essential first step, designed to prepare the selected site with power, communications, resource extraction, and initial infrastructure ensuring that when humans arrive, the habitat and support systems are already functional, safe, and economically viable.
2) Robotic outpost deployment

**Mission Goal:** Prepare the site for continuous operations and future crew habitation using two sequential robotic container deliveries utilizing existing launch vehicles such as Falcon 9 or reusable rockets will deliver standardized containers directly to the surface.

**Container 1 and 2: Utilities and Site Preparation**

**Key equipment:**

**a) Power Generation system:**

Solar power system including solar array. Compact nuclear power module for continuous supply

100 km Range Microwave Power Transmission to beam power to remote equipment

**b) Communications system:**

Direct Earth link. Local network for on -site and orbital relay

**c) Crew rovers:**

One teleoperated vehicle for site surveys and equipment transport.

**d) Mining and exploration robots:**

Teleoperated mining rover with mechanical arm and drill.

Two advanced AI humanoid robots for site assembly tasks.

Portable spectrograph for in -situ material analysis.

**e) Water extraction equipment:**

Drills and mining equipment to detect, extract and process underground ice deposits.

**f) Fuel manufacturing tests:**

Inflatable structures to be deployed for connectors, food production and manufacturing activities.

**Container 3 Complete self-sufficient human crew habitat**

Three stories habitat with:

Ground floor with lab, lockers, toilet, emergency first aid and airlock.

First floor with collective areas, command equipment, living, dining and food preparation.

Second floor with toilet and personal sleeping rooms Supplies, water and food for entire mission.

Only after the robotic outpost achieves full operational status, a first human crew will depart for the Moon (Figure 6) (Figure 7).

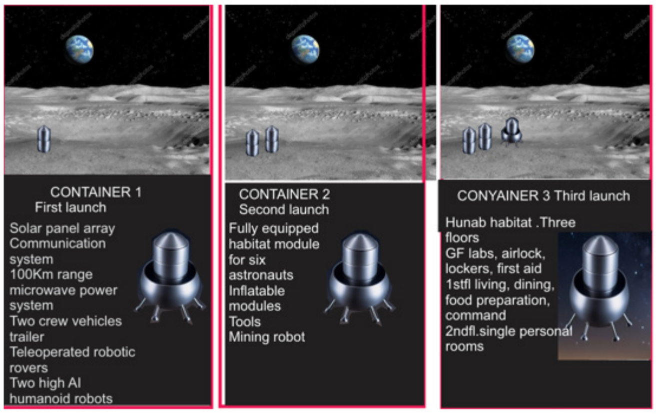


**Figure 6** Essential Moon preparation missions.

**Manned mission objectives:**

Inspect, verify, and activate all life support systems. Finalize habitat interior setup. Begin mining and mineral processing tests using local materials.

Produce lunar concrete to support expanded construction as part of lunar technologies development Map local topography in detail including resources above and underground. Conduct geological surveys and prospect for additional resources. Operate rovers to extend exploration and excavation.

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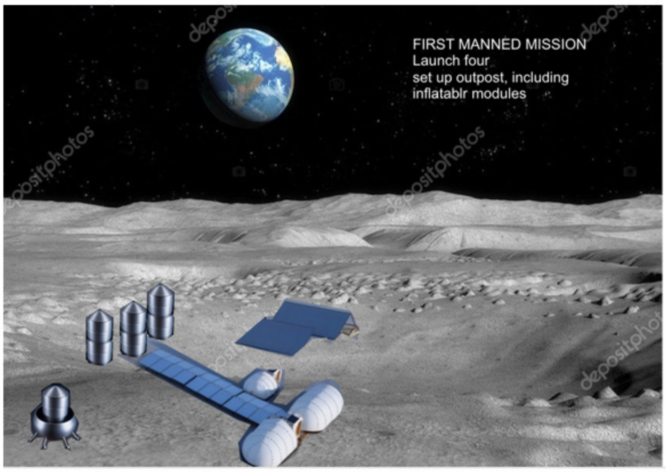


**Figure 7** First lunar outpost.

**Key principle:** Unlike Apollo, the goal is not exploration for its own sake, but establishing a permanent, productive lunar settlement that unlocks economic value and technological know-how.

**Timeline and milestones**

The Moon Essential Program is organized into several progressive development phases, each culminating in a key milestone that marks a major achievement toward long -term lunar settlement.

**Phase 1 – robotic outpost (Duration: 1 year)**

**a)** Establishment of the first robotic outpost on the lunar surface.

**b)** Primary objectives include site selection, terrain analysis, resource mapping, and deployment of basic communication and power systems.

**c)** The phase concludes once the site becomes operationally ready for human arrival.

**Phase 2 – Manned outpost and initial operations (Duration: 2 years)**

**a)** Deployment of the first human crews to the robotic outpost.

**b)** Commencement of basic lunar surface activities, including equipment testing, habitat setup, and in-situ resource utilization (ISRU) experiments.

**c)** Focus on developing sustainable life -support systems and short -term habitation capacity.

**Phase 3 – Base construction (Total program year: 5)**

a) Expansion into a permanent lunar base with integrated power, life -support, and production facilities.

b) Construction of habitats, laboratories, storage modules, and landing platforms.

c) Full deployment of automated and humanoid robotic support for construction, mining, and maintenance tasks.

**Phase 4 – Settlement expansion and network development (Ongoing)**

**a)** Transition from a single base to a network of interconnected lunar settlements.

**b)** Construction of additional bases and habitats linked by transport and communication systems.

**c)** Gradual growth into a self -sustaining lunar economy supported by research, manufacturing, and tourism activities.

## Base architecture and planning

The Moon base will combine underground and above ground structures, connected in a modular, scalable way (Figures 8–11).

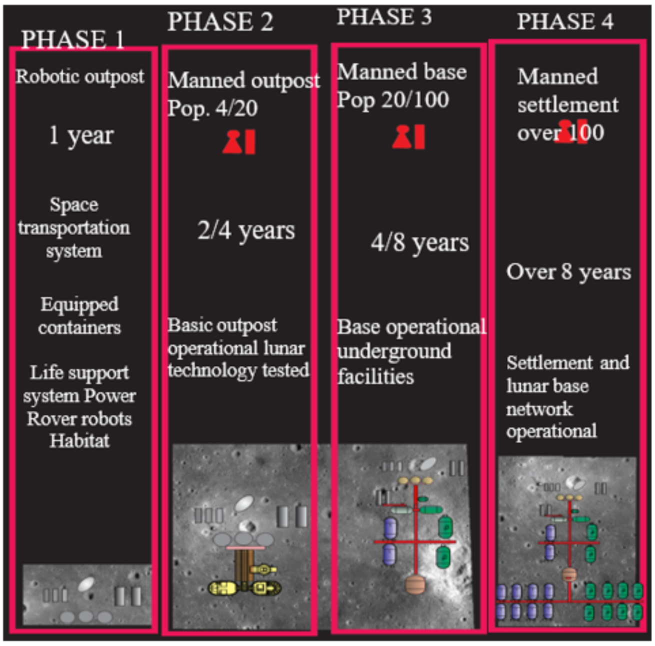


**Figure 8** Lunar settlement phase development.


**Figure 9** Initial hab

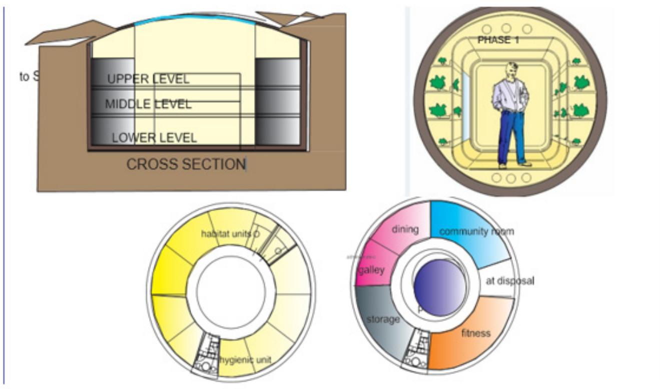


**Figure 10** Plan and secrio underground hub.

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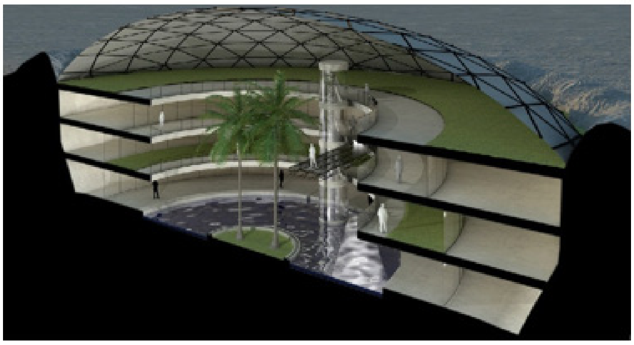

**Figure 11** Underground hub.

## Key planning elements

**Cells** — Pressurized, self-sufficient modules designed for distinct functions such as habitation, laboratories, or agricultural production. Each cell operates as an independent unit with life support, radiation shielding, and internal redundancy.

**Connectors** — Pressurized tunnels and airlocks that link cells into coherent structural networks. These ensure modular growth, maintain atmospheric integrity, and allow flexible reconfiguration as the base evolves.

**Clusters** — integrated ecosystems composed of multiple cells serving specific operational purposes—residential, agricultural, or manufacturing. Each cluster contributes to the overall self- reliance of the lunar settlement.

**Construction strategy** — subsurface construction offers natural radiation shielding and thermal stability, ensuring long-term safety and comfort. Above-ground modules will host solar arrays, mining stations, and transport hubs, forming the operational interface between the lunar surface and the underground complex.

### Transportation system

The Essential Moon proposal centers on a reusable, affordable Earth–Moon transportation network based on the Cruiser–Feeder architecture. This system ensures regular cargo and crew transfers, enabling predictable logistics and scalable operations. The same modular components can be adapted to assemble cruisers with artificial gravity for future Mars missions, demonstrating technological continuity across planetary programs.

Vertiport-style ground facilities—simple maintenance hangars and cranes—will replace costly launch complexes, drastically lowering operational barriers and democratizing access to lunar space (Figure 12) (Figure 13).


**Figure 12** Base design requirements.

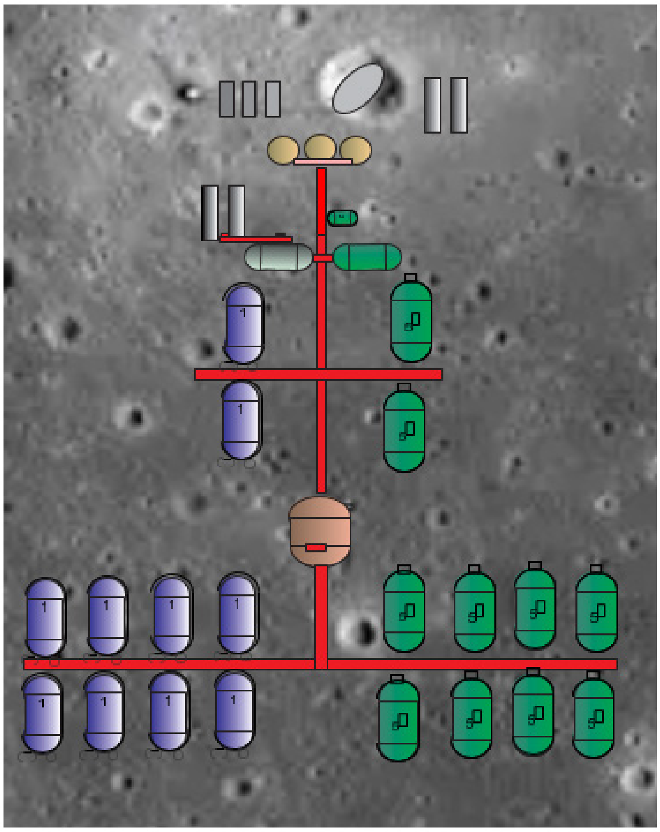

**Figure 13** Settleemnt plan.

### Expected population and cultural background

Each phase of lunar development requires specialized personnel with distinct skill sets, experience, and adaptability. The human resource composition evolves as the mission transitions from exploration to settlement.

### Phase 1 -Robotic outpost (no human presence)

### Phase 2 – Outpost Assembly and Operations

**a.** Crew Duration: Approximately 1 month per mission.

**b.** Initial Population: Up to 10 crew members.

**c.** Primary Roles:

i. Pilot

ii. Logistics Engineer

iii. Medical Officer / Doctor

iv. Geologist

v. Manufacturing and Construction Specialists

**d.** Support Teams: Remote support from food processing and systems engineering teams.

**e.** Automation: Humanoid and non -humanoid robots perform housekeeping, repetitive operations, surface exploration, and external maintenance tasks.

### Phase 3– Base construction

**a.** Crew Size: 20–50 personnel.


DOI: 10.15406/aaoaj.2025.09.00237

 

**b.** Mission Duration: 3–6 months, rotational.

**c.** Key Skills:

i. Construction and Structural Engineering

ii. Mining and Resource Processing

iii. Manufacturing and Fabrication

iv. Food and Water Production

v. Logistics, Flight Operations, and Medical Support

**d.** Age Range: 30–60 years old, with preference for experienced personnel in high -stress and isolated environments.

**Phase 4 – Settlement development**

**a. Population**: Expanding to 100+ personnel as infrastructure matures.

**b. Skill base**: All major disciplines required for a self-sufficient, business -oriented lunar community, including governance, education, communication, trade, and cultural activities.

**c. Objective**: Transition from a research outpost to a permanent lunar settlement with diversified economic and social structures (Figure 14).

| ACTIVITY | Phase 1 | | Phase 2 | | Phase 3 | | Phase 4 | |
|---|---|---|---|---|---|---|---|---|
| | Human | AIbot | Human | AIbot | Human | AIbot | Human | AIbot |
| Transportation | | | 1 | | 2 | | 4 | |
| Life support | | 1 | 2 | | 3 | 6 | 8 | 30 |
| Health care | | | 1 | 4 | 2 | 6 | 6 | 10 |
| Food processing | | 1 | 2 | 6 | 6 | 6 | 15 | 30 |
| Research | | 1 | 1 | 6 | 6 | 4 | 4 | 6 |
| Construction | | 2 | 2 | 4 | 4 | 20 | 10 | 40 |
| Fuel production | | | 1 | 4 | 4 | 6 | 10 | 6 |
| Mining | | 1 | 3 | 6 | 6 | 20 | 10 | 40 |
| Mineral processin | | | 3 | 4 | 4 | 20 | 10 | 40 |
| Manufacturing | | | 1 | 4 | 4 | 4 | 15 | 40 |
| Assembly | | | 1 | 4 | 4 | 10 | 6 | 6 |
| local transportation | | | | | 1 | 6 | 6 | 6 |
| science | | | 1 | 6 | 3 | 6 | 15 | 6 |
| Maintenance | | | 1 | 6 | 3 | 6 | 30 | 60 |
| business | | | | | 4 | 2 | 40 | 10 |
| specialized | | | | | | | 40 | 10 |
| TOTAL | – | 6 | 20 | 50 | 50 | 120 | 200+ | 300+ |

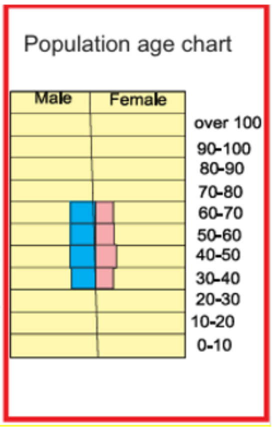


**Figure 14** Population chart.

## Economic objective

The ultimate purpose of the Essential Moon initiative is not merely to revisit the Moon, but to build a functional lunar economy that supports long -term habitation, industry, and research. Economic sustainability will emerge through:

**a.** Extraction and processing of lunar regolith to produce oxygen, water, and rocket fuel.

**b.** Development of lunar concrete and alloys for construction using in -situ materials.

**c.** Establishment of autonomous manufacturing for spare parts and modular expansion.

**d.** Implementation of commercial partnerships to develop power, communication, and logistics services.

**e.** Creation of scientific and industrial zones, fostering international and private collaboration.

**Recommendations**

To ensure success, the Essential Moon program must be governed by a comprehensive Master Plan with the following strategic principles:

I. Simplicity and modularity — each component must serve multiple purposes and integrate seamlessly with future systems.

II. Full reusability — all vehicles and equipment should minimize waste and cost per mission.

III. AI and robotics first — Robotic precursors must construct, maintain, and expand infrastructure autonomously before human arrival.

IV. In-situ resource utilization (ISRU) — Prioritize the use of local materials to reduce Earth dependency.

V. Incremental human presence — Send crews only after infrastructure is operational and self-sustaining.

VI. Public–private cooperation — Encourage international partnerships to distribute cost and stimulate innovation.

VII. Economic vision — Treat the Moon as a commercial and industrial frontier, not a symbolic target.

In summary, the Robotic Outpost and First Moon Base are the foundation of a scalable, enduring lunar civilization. Through autonomous preparation, modular design, and disciplined planning, the Essential Moon strategy transforms the Moon from a destination into a permanent extension of human civilization — a living, productive world that will anchor humanity's expansion across the Solar System.[1–25]

## Conclusion: The moon as humanity's second genesis

The Essential Moon program represents more than a return —it is a rebirth of purpose. It calls for a pragmatic yet visionary approach: reusable technology, robotic precision, and a modular growth model. Through disciplined planning, AI coordination, and shared international collaboration, we can achieve a permanent lunar foothold within years not decades.

The Moon is not an endpoint —it is a beginning. A proving ground for the technologies, ethics, and unity that will one day carry humanity across the Solar System.

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The Essential Moon project marks the beginning of a new chapter in human evolution —one defined not by brief exploration but by sustained habitation and development beyond Earth. The Moon, our nearest celestial neighbor, offers the ideal platform to test, refine, and implement the technologies, systems, and social models that will support humanity's long -term survival in space. It is the natural bridge between our planetary past and our interplanetary future.

Unlike previous missions driven by competition or prestige, Essential Moon is guided by a unified Master Plan focused on permanence, practicality, and progress. Each step —robotic preparation, infrastructure deployment, and human arrival —is designed to build upon the last, forming an integrated ecosystem of logistics, habitation, and production. The establishment of reusable transportation systems, modular habitats, and in situ resource utilization ensures that lunar operations evolve toward self -sufficiency rather than dependence on Earth.

The arrival of the first human crew will mark more than a symbolic return it will initiate a permanent industrial, scientific, and economic presence on the Moon. By mining resources, processing materials locally, and experimenting with lunar construction methods, humanity will create the foundation for autonomous growth. This effort will not only open vast new opportunities in science and commerce but also secure Earth's long-term safety and prosperity.

Ultimately, Essential Moon is more than a space program —it is a civilizational strategy. It redefines the purpose of space exploration from discovery to creation, from visitation to habitation. The lessons learned on the Moon will extend to Mars and beyond, ensuring that humanity's expansion through the Solar System proceeds in a structured, sustainable, and cooperative manner. In embracing this vision, we lay the cornerstone of a true spacefaring civilization one capable of shaping its destiny among the stars.

## Acknowledgements

None.

## Conflicts of interest

The author declares that there are no conflicts of interest.

## Funding

None.

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**Citation:** Gaviraghi G. Essential Moon:A framework for permanent lunar development. *Aeron Aero Open Access J.* 2025;9(4):184–191.
DOI: 10.15406/aaoaj.2025.09.00237