Towards a Self-Sustaining Lunar Base: An LSIC Community South Pole Master Planning Approach.

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Introduction The Lunar Surface Innovation Consortium (LSIC) is a collaborative network operated by the Johns Hopkins Applied Physics Laboratory (APL) for NASA's Space Technology Mission Directorate (STMD). The LSIC brings together stakeholders from industry, academia, government agencies, and non-profits to foster collaborative development and implementation of technologies essential for establishing a sustained human and robotic presence on the Moon and beyond.

Central to this mission is the recognition that the establishment of a sustainable Lunar base requires a comprehensive, systems-level approach. Such an approach must integrate multiple technical domains—power generation, in-situ resource utilization (ISRU), mobility, habitation, and logistics—into a unified infrastructure strategy. Expansion of our Lunar presence is not only foundational to achieving NASA's Moon-to-Mars (M2M) objectives but also enables long-duration exploration and serves as a crucial stepping stone for deeper space missions to Mars and beyond.

There is a unique opportunity at this stage of Lunar development to better align across NASA's evolving goals and the broader community's needs for lunar surface infrastructure. In 2024, in response to community interest, the Excavation and Construction Capability area of the LSIC undertook a collaborative effort to develop an initial lunar base concept, integrating cross-sector perspectives on infrastructure requirements, site feasibility, and system interdependencies. This process provides a mechanism to communicate community-driven insights and priorities to help inform future NASA planning and advancing technologies. This abstract summarizes accomplishments to date and outlines the next steps in developing a systems-based framework that supports phased lunar base development and long-term exploration goals.

Approach & Methodology: The master planning effort follows a community-driven, phased approach that integrates efforts from across stakeholders to perform system modeling, trade studies, and definition of use cases. Through a series of workshops, technical exchanges, and collaborative modeling efforts conducted in 2024, the LSIC community has helped shape the underlying assumptions and priorities used in this planning process. This structured methodology ensures that each phase of development builds upon validated capabilities and reflects input from a diverse range of technical and operational perspectives. The approach is divided into three primary phases: an initial expeditionary base, an industrial-scale outpost with refueling capabilities, and a long-term, self-sustaining lunar settlement. Continued community engagement will guide further efforts.

The first phase, the Expeditionary Base, focuses on the deployment of robotic scouting missions, establishing initial power generation, and mobility systems. Early infrastructure development will involve small-scale surface operations, such as modular power generation using vertical solar arrays or compact fission units, robotic excavation for regolith processing, and prototype habitation modules designed to test environmental controls and radiation shielding. There is strong community interest in this phase to begin to aggregate and co-locate these systems, demonstrating basic interoperability and integrated operations across power, mobility, and ISRU nodes, which can enable new service markets for commercial providers and reduce reliance on elements that are self-contained within a mission.

As operations scale toward an intermediate base with expanded logistics capabilities, ISRU systems may scale up to support large-scale oxygen or water production, enabling the development of a lunar refueling depot to support deep-space missions. The integration of an interconnected microgrid and advanced mobility systems could facilitate efficient distribution of resources and crew transport. Expansion of lunar landing pads, storage facilities, and modular habitats may further enhance the operational capacity of the lunar base.

The final phase, a longer term lunar base, focuses on the transition to industrial-scale ISRU and manufacturing. In this phase, a lunar base could also support commercial logistics operations, space-based research laboratories, and staging facilities for deep-space missions.

Infrastructure Systems Overview

Presented at the LSIC Fall Meeting, this figure illustrates the extensibility of the framework, here applied to a 50-person lunar base. Developed by the LSIC community, it maps interdependencies across power, ISRU, habitation, and mobility systems to support long-term planning and trade studies. This network-based lunar infrastructure model approach can enable simulation of mass and energy flows, logistics, and mobility across critical nodes—such as habitation, ISRU, power generation, and the spaceport. Some elements of the model are described below.

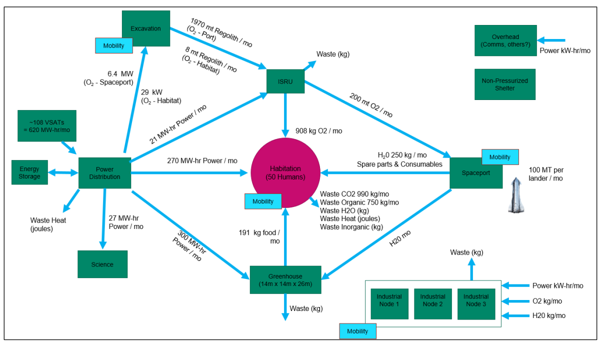

Figure 1: Notional 50-Person Lunar Base

Excavation and ISRU: Robotic excavation systems such as NASA's RASSOR and IPEx prototypes will be deployed to mine regolith for oxygen extraction and building materials. A single excavator can process ~1–2.7 tons/day; a network of autonomous units will be coordinated to meet base-level demands. Excavated material will feed into ISRU plants that use molten regolith electrolysis or carbothermal reduction to produce oxygen, iron, and silicon.

Power Generation and Storage: The power strategy includes deployable solar panels at high-altitude sites and fission reactors like FSP. Systems will be connected via a reconfigurable microgrid. Energy storage includes lithium-ion batteries and regenerative fuel cells to span the lunar night. Trade studies could evaluating optimal combinations of energy sources for different mission phases and contingencies.

Mobility and Logistics: Surface operations will rely on a fleet of unpressurized rovers, pressurized crew vehicles, and autonomous haulers for material transport. These systems will share standardized interfaces for docking, charging, and cargo exchange. Long-term mobility infrastructure may include graded roads and robotic path maintenance to minimize dust interference and support continuous logistics.

Results & Expected Outcomes: This effort aims to leverage the community to mature a framework and use it to describe a reference lunar base. These outputs can enable aligned roadmaps that meet commercial and other stakeholder needs, while aligning with NASA's Artemis and Moon-to-Mars initiatives.

The community-informed lunar infrastructure planning framework presented here is intended to support broader efforts across government, industry, and academia by providing a community-derived reference for evaluating infrastructure needs and development strategies. Rather than prescribing a definitive approach, this product offers a notional baseline that stakeholders can use to explore technology integration, resource utilization, and scalable deployment options.

References: [1] NASA. (2024). Moon to Mars Architecture Definition Document (ESDMD-001)
[2] Ewert, M. K., & Stromgren, C. (2019). Astronaut Mass Balance for Long Duration Missions.