TEAM PROMETHEUS: LUNAR NUCLEAR REACTOR AND RAIL ENGINEERING

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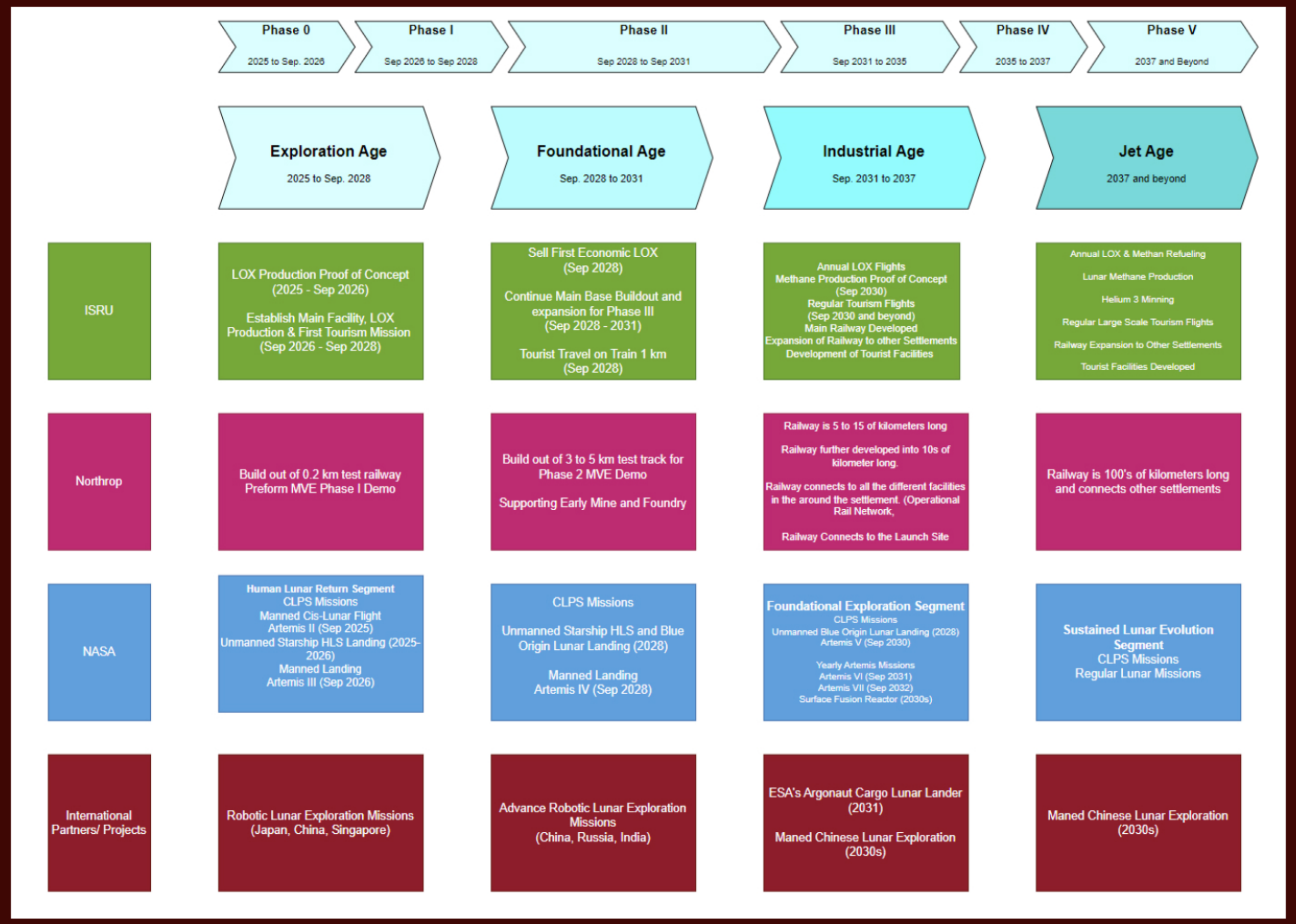
PROJECT PHASING

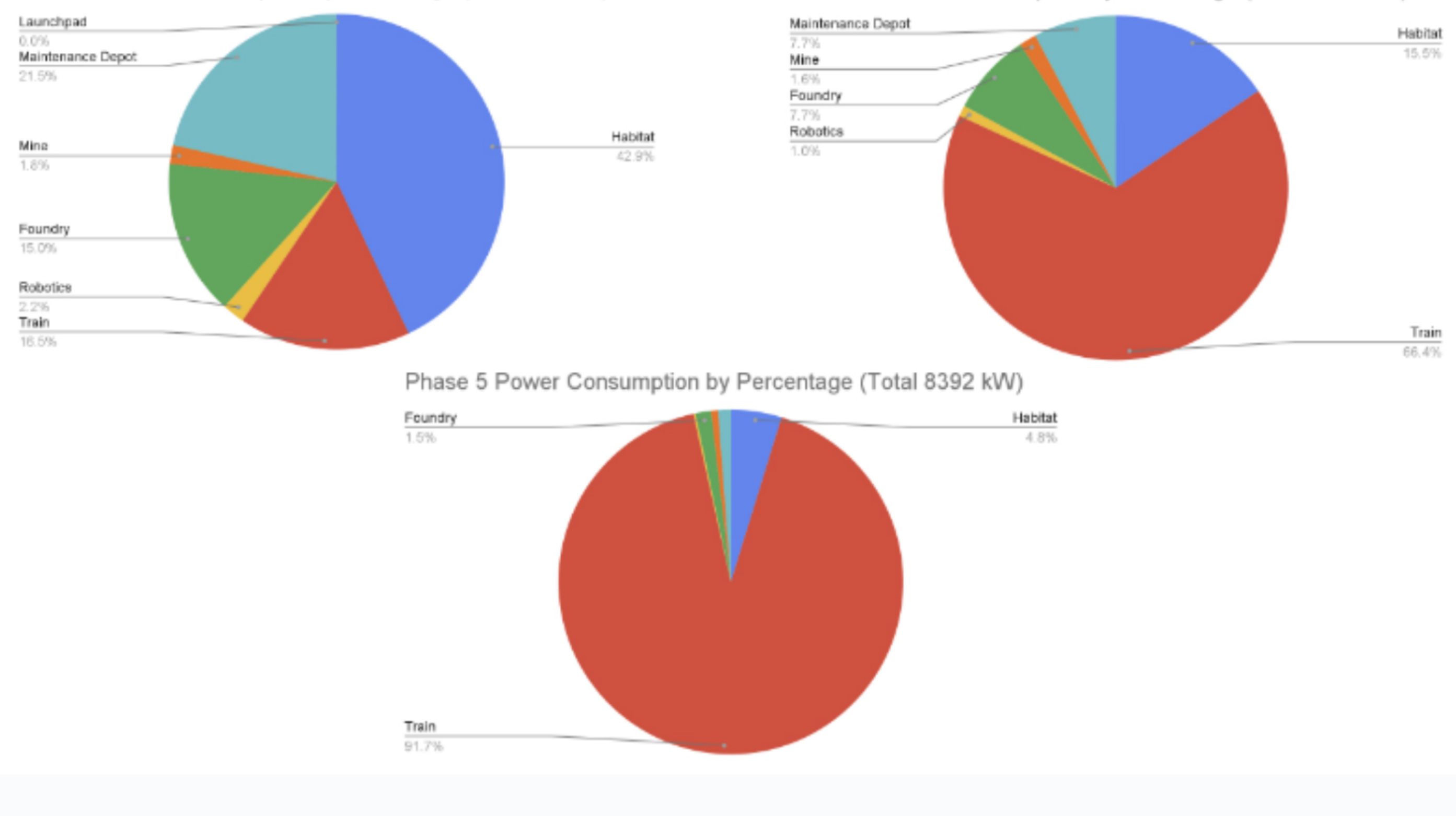
The Initial Deployment and Construction phase marks the foundational stage of lunar infrastructure development at the C1 landing site, positioned between de-Gerlache and Shackleton craters. This site is selected for its strategic benefits, including proximity to a Permanently Shadowed Region (PSR) and access to continuous solar energy from elevated terrain. SpaceX's Starship will deliver essential components, setting the stage for long-term operations. Initial construction will include a railway system, a lunar train, robotic units, and the deployment of the Honeybee LUNARSABER Tower, which will provide 150 kW of power. A crew of 2-6 astronauts will oversee these activities, initiating small-scale liquid oxygen (LOX) mining near Shackleton crater. This initial phase paves the way for expanding infrastructure and resource extraction in subsequent phases, ultimately contributing to the establishment of a sustainable lunar economy.



Phase 0 2025 to Sep. 2026 | Phase I Sep 2026 to Sep 2028 | Phase II Sep 2028 to Sep 2031 | Phase III Sep 2031 to 2035 | Phase IV 2035 to 2037 | Phase V 2037 and Beyond

	Exploration Age 2025 to Sep. 2028	Foundational Age Sep. 2028 to 2031	Industrial Age Sep. 2031 to 2037	Jet Age 2037 and beyond
ISRU	LOX Production Proof of Concept (2025 - Sep 2026) Establish Main Facility, LOX Production & First Tourism Mission (Sep 2026 - Sep 2028)	Sell First Economic LOX (Sep 2028) Continue Main Base Buildout and expansion for Phase III (Sep 2028 - 2031) Tourist Travel on Train 1 km (Sep 2028)	Annual LOX Flights Methane Production Proof of Concept (Sep 2030) Regular Tourism Flights (Sep 2030 and beyond) Main Railway Developed Expansion of Railway to other Settlements Development of Tourist Facilities	Annual LOX & Methan Refueling Lunar Methane Production Helium 3 Minning Regular Large Scale Tourism Flights Railway Expansion to Other Settlements Tourist Facilities Developed
Northrop	Build out of 0.2 km test railway Preform MVE Phase I Demo	Build out of 3 to 5 km test track for Phase 2 MVE Demo Supporting Early Mine and Foundry	Railway is 5 to 15 of kilometers long Railway further developed into 10s of kilometer long. Railway connects to all the different facilities in the around the settlement. (Operational Rail Network, Railway Connects to the Launch Site	Railway is 100's of kilometers long and connects other settlements
NASA	**Human Lunar Return Segment** CLPS Missions Manned Cis-Lunar Flight Artemis II (Sep 2025) Unmanned Starship HLS Landing (2025-2026) Manned Landing Artemis III (Sep 2026)	CLPS Missions Unmanned Starship HLS and Blue Origin Lunar Landing (2028) Manned Landing Artemis IV (Sep 2028)	**Foundational Exploration Segment** CLPS Missions Unmanned Blue Origin Lunar Landing (2028) Artemis V (Sep 2030) Yearly Artemis Missions Artemis VI (Sep 2031) Artemis VII (Sep 2032) Surface Fusion Reactor (2030s)	**Sustained Lunar Evolution Segment** CLPS Missions Regular Lunar Missions
International Partners/ Projects	Robotic Lunar Exploration Missions (Japan, China, Singapore)	Advance Robotic Lunar Exploration Missions (China, Russia, India)	ESA's Argonaut Cargo Lunar Lander (2031) Maned Chinese Lunar Exploration (2030s)	Maned Chinese Lunar Exploration (2030s)

POWER ALLOCATION BY PHASE



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BACKGROUND

The objective of the lunar nuclear reactor project is to enable increased access to permanently shadowed regions of Shackleton crater, thus enabling procurement of the frozen water found within, while also increasing the robustness of the power available on the lunar surface outside Shackleton crater. This will serve to further the development of a human presence on the lunar surface as well as a lunar economy, which will itself drive the development of space exploration as a whole.

The rail network is a train and railway system on the lunar surface. The team has identified a few key reasons as to why it may be beneficial to develop rail infrastructure on the moon. First, the complexity of maintenance would be significantly less. The moon's extreme temperatures and dust problems mean that maintenance is a considerable challenge when developing infrastructure. Having all of the lunar economy's main components within the same train system would simplify maintenance, reduce contact with lunar dust, and provide the ability to combat the extreme temperatures by using the train's mobility to move to more favorable conditions when needed. Furthermore, the modularity of the train would make maintenance all the more easier. Secondly, utilizing a railway system could make transportation of resources such as LOX to the launchpad significantly easier and require less power overall. Third, the train offers opportunities for tourism, which will further advance commercialization of the lunar economy. Finally, the scalability of the railway system means that as this economy grows, we could easily build upon the railway system and expand it to the parts of the lunar surface which we desire.

We have elected to place the reactor on the lunar train, which is to be implemented in the region surrounding and including Shackleton crater. Shackleton crater is easily identifiable as a ROI; the possibility of it containing water ice alone makes the site worth looking into, but its unique positioning as a PSR surrounded by terrain which is almost constantly illuminated makes it an ideal candidate for lunar surface operations, especially those which should rely on solar power to some extent (but which should not rely upon it solely!). Thus, the decision to base the lunar railroad around Shackleton crater was very straightforward.

Shackleton Crater as imaged by Earth-based radar

REACTOR POWER TIME CYCLE

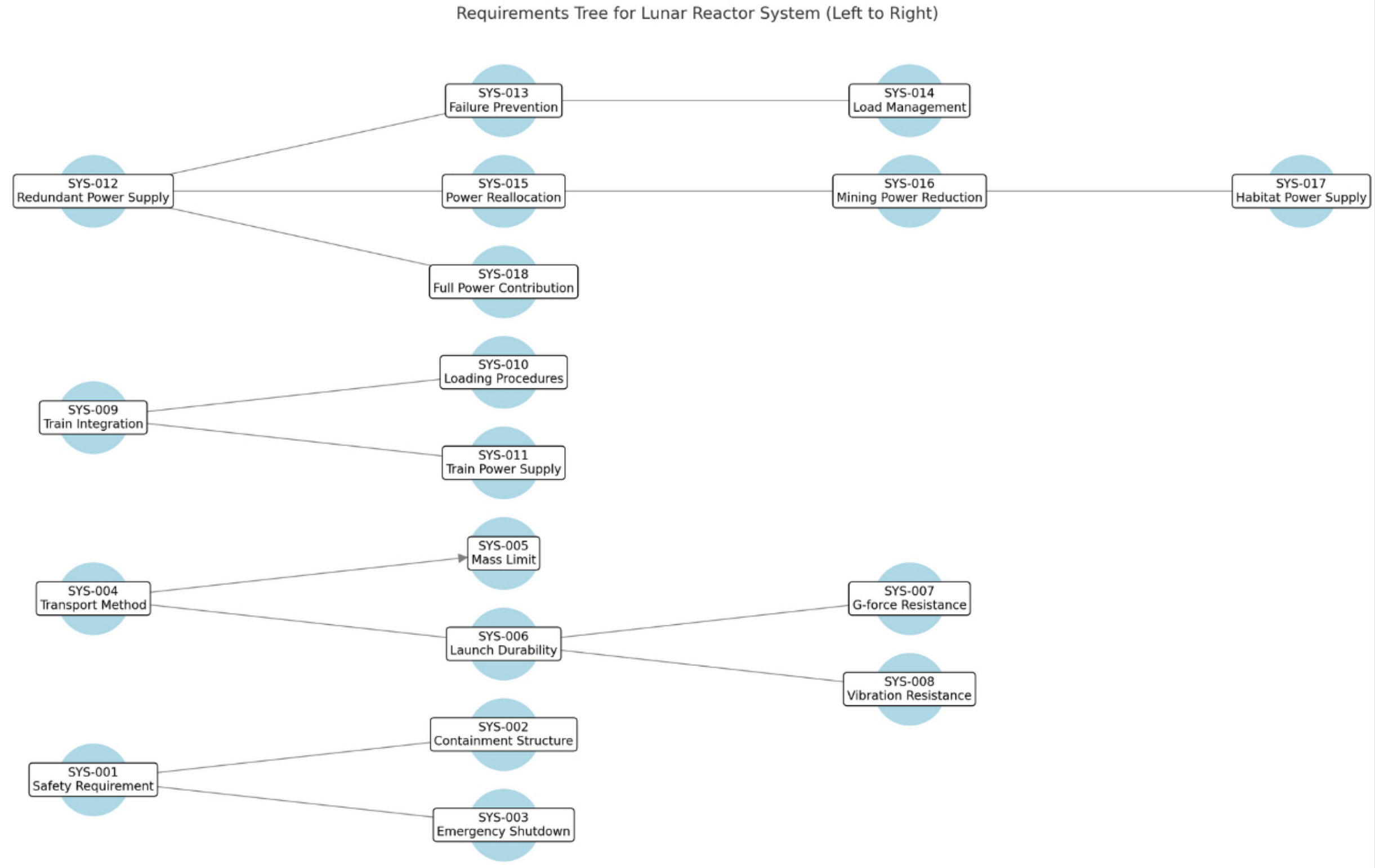
The 24-hour time cycle for reactor power draw outlines the strategic allocation of energy to support various phases of lunar operations. Each phase is designed to balance power needs with operational goals, ensuring the efficient use of the microreactor. Starting from peak power for critical startup tasks to steady power for ongoing mining and maintenance, and reducing power during night shifts to conserve energy while maintaining essential functions, this cycle enables optimized management of resources on the lunar surface.

Given that parts of the ridges of Shackleton Crater are illuminated 80-90% of the time, specific alignments of lighting conditions with a 24 hour cycle are suboptimal. For example, if startup and mining operations were to be scheduled during a period of darkness, additional strain might be placed on the reactor. Of course, this risk can be mitigated by having a large enough store of energy ready on demand, but this may require advantageous light cycles occurring in prior 24 hour cycles.

Table 1: 24 Hour Time Cycle for Reactor Power Draw

Operational Phase	Time Period (UTC)	Time Period (CDT)	Power Draw (kWe)	Primary Operations
Phase 1: Peak Power for Startup and Operations	04:00 - 08:00	23:00 – 03:00	200 - 250 kWe	- Initialize habitat systems (lighting, thermal regulation). - Activate mining operations in Shackleton Crater. - Power up the foundry for early processing. - Begin operations on the lunar train for resource transport.
Phase 2: Steady Power for Maintenance and Mining	08:00 - 18:00	03:00 – 13:00	150 - 200 kWe	- Maintain stable habitat and life support. - Full-scale mining operations. - Full foundry operations for processing mined resources. - Continuous rail transport between mining zones, foundry, and processing facilities.
Phase 3: Reducing Power for Night Shift, Peak Earth Communication	18:00 - 22:00	13:00 – 17:00	120 - 200 kWe	- Ramp down mining to lower-power mode. - Scale back foundry operations, focusing on minimal processing activities. - Limited rail transport (idle mode). - Reduced power for habitat systems as the crew prepares for the night shift. - Optional peak of communication with Earth due to reducing crew operations in tandem with an ideal CDT time.
Phase 4: Off-Peak Period (Night Shift)	22:00 - 04:00	17:00 – 23:00	120 - 150 kWe	- Minimized habitat systems (life support at baseline level, reduced lighting). - Minimal mining and foundry operations (standby mode or operation at minimum capacity). - Lunar train not actively traveling.

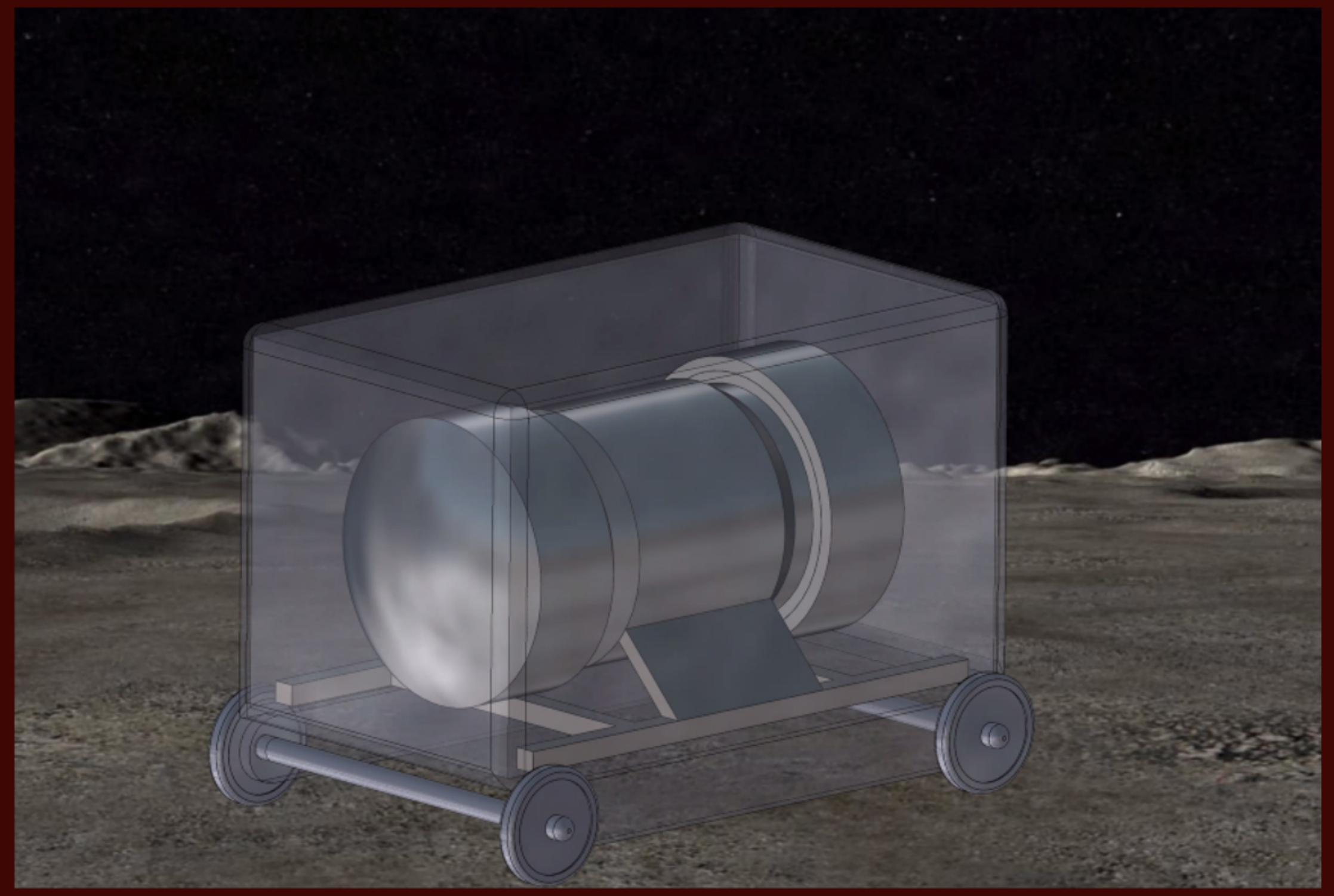
REQUIREMENTS



The project requirements for the lunar nuclear reactor are centered around safety, functionality, and integration within a broader lunar economy.

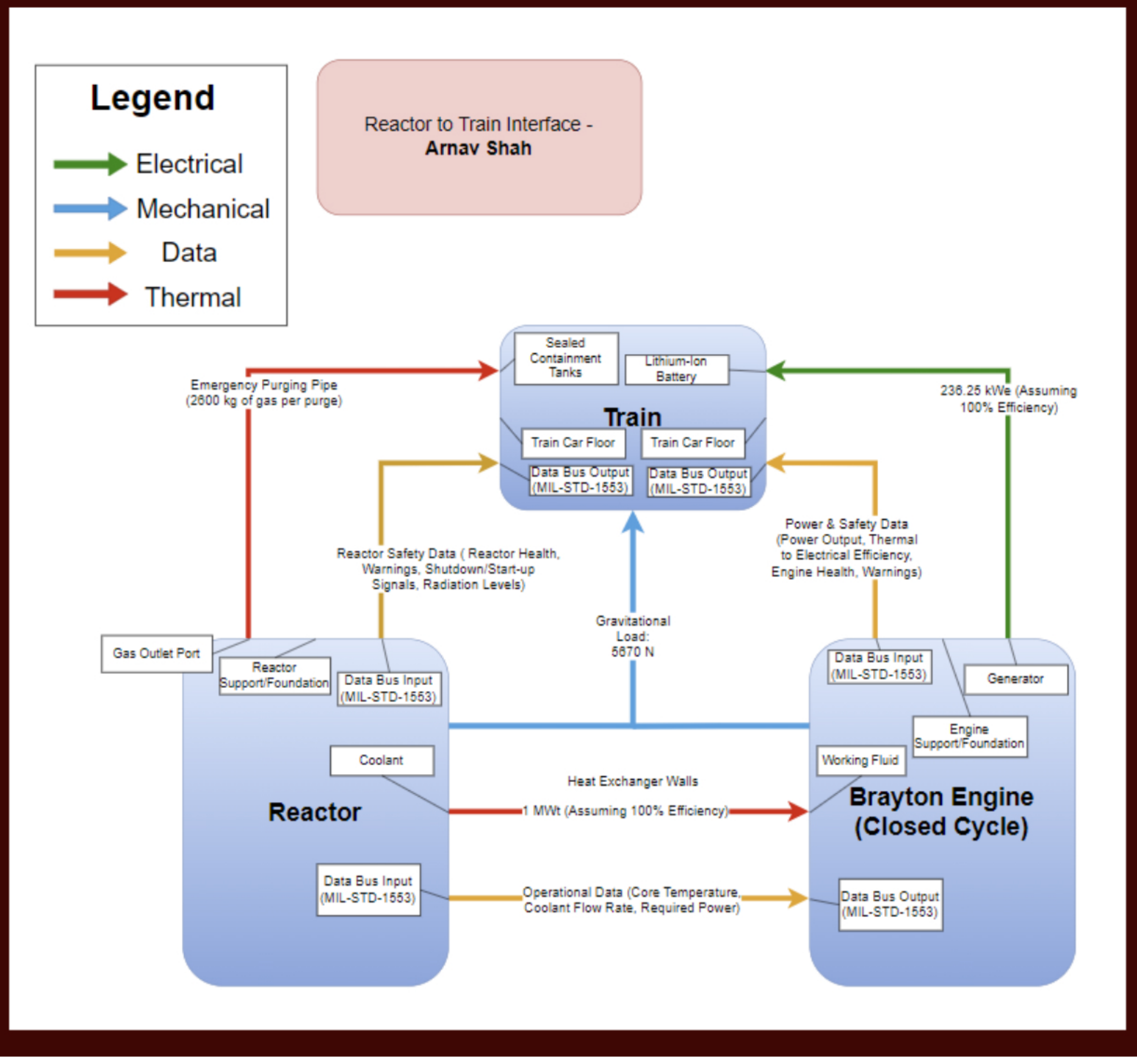
SYS-001, mandates that the reactor must not pose any danger to humans on the lunar surface, reflecting the paramount importance of human safety. To meet this, the reactor includes a containment structure (SYS-002) that limits radiation exposure to 4 mSv/yr, comparable to Earth's average radiation levels. A manual scram mechanism (SYS-003) ensures rapid fission halt capability for emergency shutdowns. The reactor's transport logistics (SYS-004) stipulate compatibility with commercial lunar transporters, such as CLPS landers (with a mass limit of 1,000 kg) or Starship (up to 100,000 kg). To withstand launch conditions, the reactor must be resilient to both g-forces (SYS-007) and vibrations (SYS-008). For operational integration, the reactor will interface with the lunar train network (SYS-009), facilitating power transfer (SYS-011) and including specific loading and unloading procedures (SYS-010). The reactor's power output (SYS-014, SYS-017) is designed to maintain habitat functions at 200 kWe during emergencies and provide up to 350 kWe during normal operations, supporting fault-tolerant, redundant power allocation (SYS-012, SYS-015, SYS-018). This careful planning reflects a comprehensive approach to ensure reliability, safety, and adaptability in lunar surface power management.

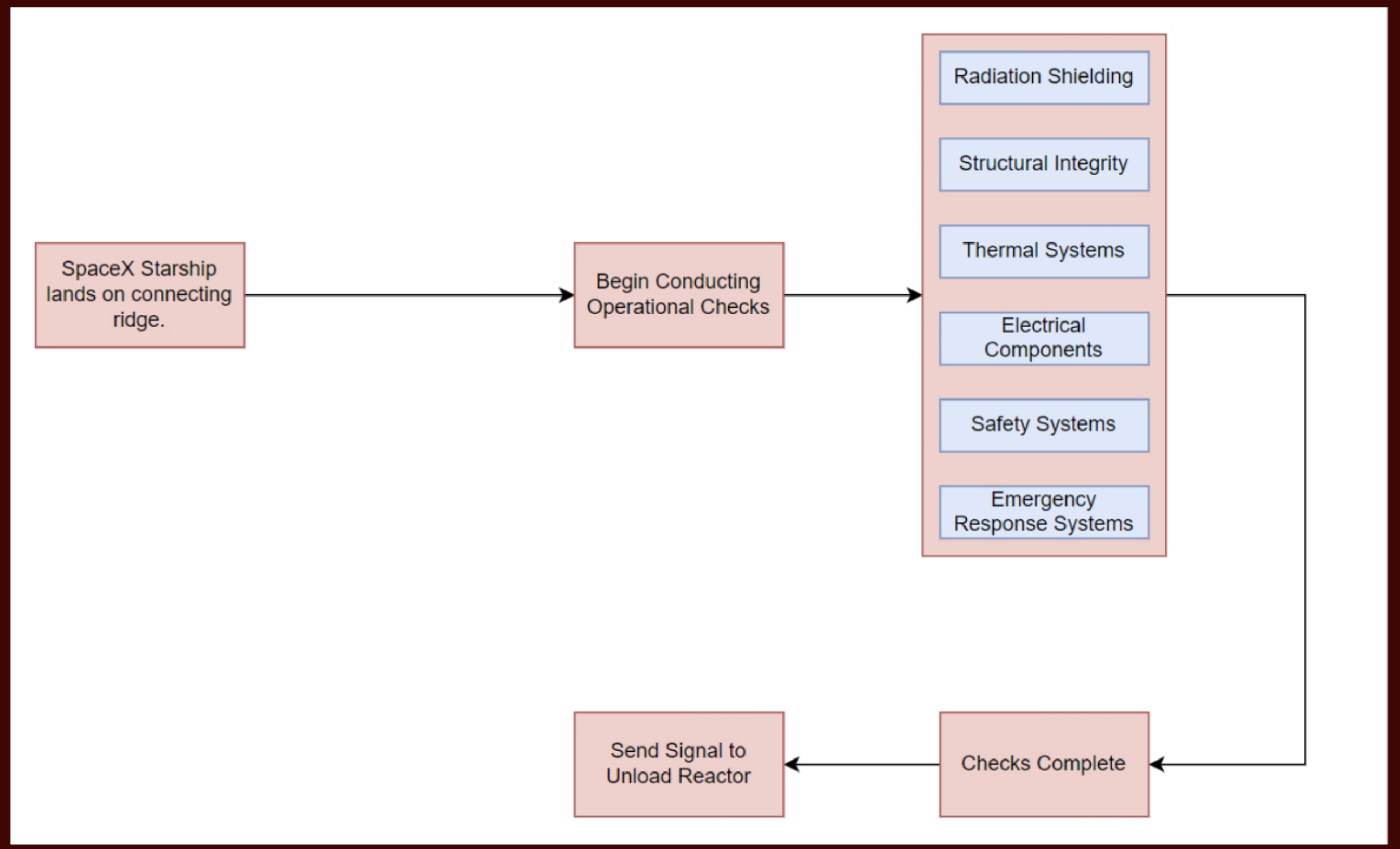
REACTOR DESIGN AND SELECTION



A micro reactor is a small, efficient nuclear power source that provides continuous energy with minimal maintenance. Its compact design and reliability make it ideal for use on the Moon, where long periods of darkness limit solar power. On the Moon, micro reactors can be used not only for a lunar rail system to transport materials and resources but also to power habitats, research stations, and industrial operations such as mining and processing lunar regolith. This consistent energy source is essential for sustaining human presence, supporting exploration missions, and enabling the growth of a lunar economy by facilitating construction, communication systems, and life support infrastructure.

INTERFACING & CONOPS





SpaceX Starship lands on connecting ridge.

Begin Conducting Operational Checks

- Radiation Shielding
- Structural Integrity
- Thermal Systems
- Electrical Components
- Safety Systems
- Emergency Response Systems

Checks Complete

Send Signal to Unload Reactor