Lunar In-Situ Surface Construction of Infrastructure

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INTRODUCTION

Over the years, mission concepts for the Moon and for Mars have depicted surface infrastructure indicating varying levels of construction and manipulation of indigenous resources to create landing pads, shielding, berms, and roadways (See Figure 1). Other literature suggests constructing structures using basalt or with hydrated concrete mixtures, sintering regolith in place, or covering with regolith by using inflatable and other pressurized containers to serve as crew habitats. Recent concerns of ejecta and space debris being created by large landers suggests a movement to explore options for landing and launch pads on the Lunar and Martian surface. Some requirements are emerging for using regolith to shield habitats from Galactic Cosmic Ray (GCR) radiation reaching the Lunar and Martian surfaces. However, in the absence of requirements for surface construction, and in some cases, surface infrastructure selections in general, it is difficult to assess and trade options and opportunities. The recently announced NASA Artemis Program for returning astronauts to the "Lunar Surface to Stay by 2024" establishes some "Goals, Needs, and Objectives" that may lead to the development of requirements. However, requirements development may not be straight forward given that utilizing indigenous resources, termed in situ resource utilization (ISRU), for construction and surface infrastructure is so new and available resources are ill defined. The highly successful Apollo Program did not depend on ISRU. However, those missions were not intended for long surface stays. Hence, the Artemis Program is quite different, since it has the goal of being sustainable, which increases a likely dependence on long term utilization of in-situ resources.

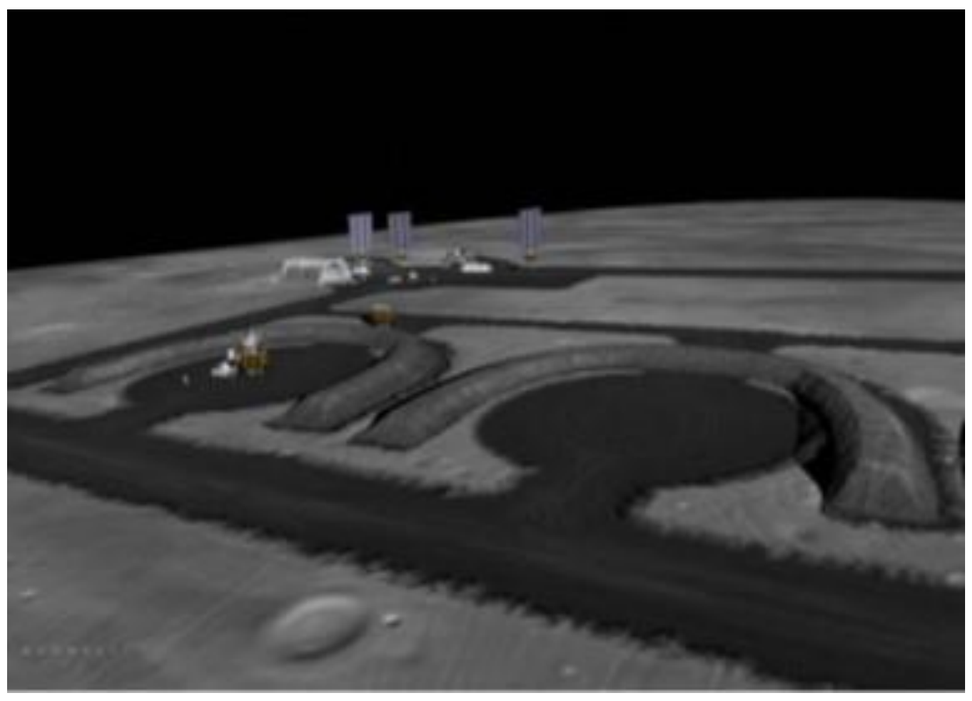

Figure 1. Lunar Base Infrastructure Concept

CURRENT UNDERSTANDING OF CONSTRUCTION NEEDS

Because of the multidisciplinary nature of the aerospace systems needed for human exploration, the SCLT on ISRU created an ISRU Construction Integrated Steering Group (ISG), including multiple NASA field centers, that combines expertise among several NASA Principal Technologists and Capabilities Leaders for exploring options, assessing opportunities, and developing requirements for construction and manufacturing on the Moon and Mars. Figure 2 shows a notional framework for developing requirements for future lunar infrastructure development. Inputs are welcomed from all.

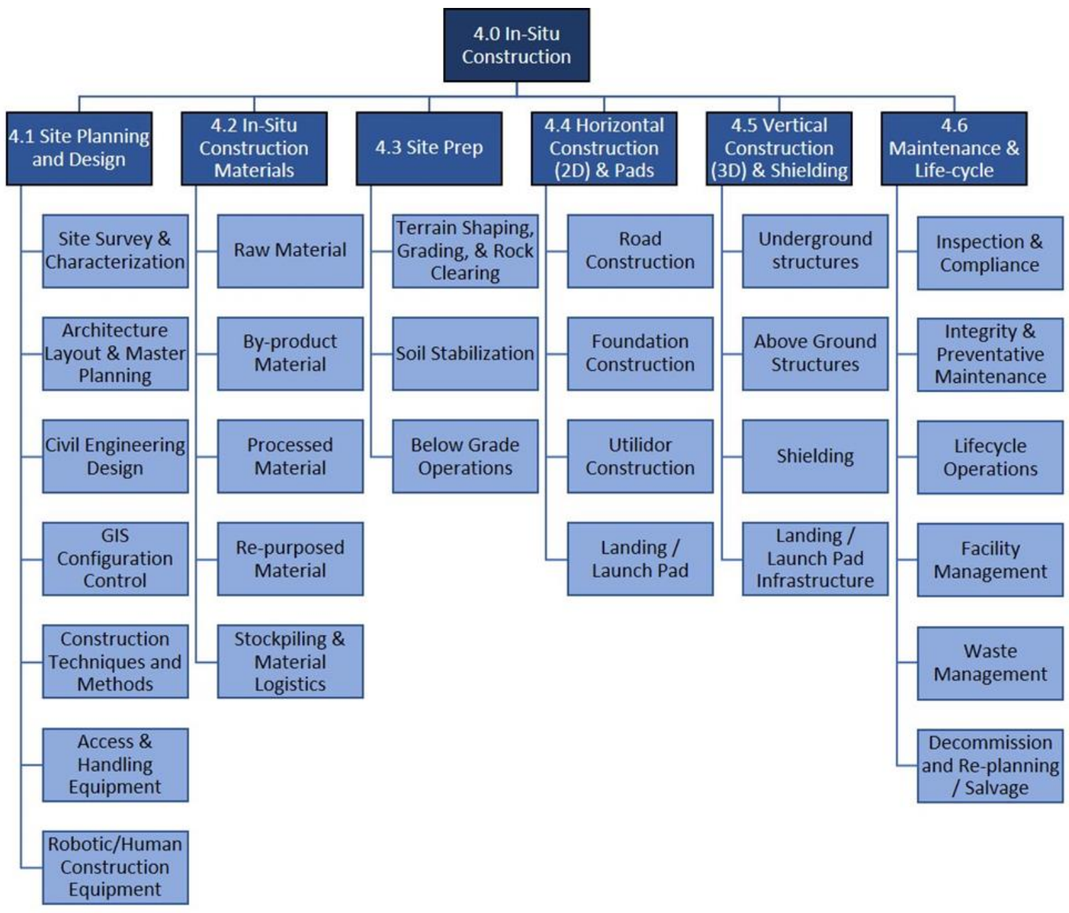

Figure 2. Proposed Work Breakdown Structure to Align with Construction Industry Terminology

CONCLUSIONS

When a lander vehicle launches or lands on an extra-terrestrial body, the rocket engine exhaust plume impinges on the surface and creates an interaction with the regolith which creates blast effects. It is likely that landing & launch pads will be required. Some preliminary work in planetary construction and manufacturing has yielded successes and raised awareness of its potential to enable sustainable operations on the Lunar and Martian surfaces. Construction activities will likely require converting indigenous resources into serviceable operational systems for infrastructure, rather than making those structures on Earth then landing and emplacing them on the lunar surface. In general, based on terrestrial construction best practices and fundamental research using regolith simulants, converting regolith to usable products requires high power. Considering this, the following recommendations are offered:

- Need to establish requirements for surface construction and clearly delineate those for the Lunar and Mars surfaces to enable appropriate priorities and funding timelines
- Need a focused program that advances Technology Readiness Level (TRL) for construction technologies and surface power system, specifically one that effectively leverages lessons learned from earth construction and excavation
- Consider using the bulk regolith "as is" as the baseline, or the lowest energy approach to construction of infrastructure on the lunar surface to trade alternatives against
- For construction and excavation technologies, capabilities and methods, use lunar surface to prepare for Mars as much as feasible and realistic
- Encourage modularity/extensibility

A logical framework has been developed which will be used to inform the development of requirements for future NASA funded work. The development of these requirements is crucial to allow industry, academia and government to focus their efforts on relevant needs.

BIBLIOGRAPHY

Metzger, P. T. and Brit, D. T., "Mitigating Lander Plume Effects With Space Resources," Lunar ISRU 2019: Developing a New Space Economy (2019), Paper No. 5055, Developing a New Space Economy Through Lunar Resources and Their Utilization, Lunar and Planetary Institute, Universities Space Research Association, NASA Lunar Exploration Analysis Group, July 15–17, 2019, Columbia, Maryland

Mueller, R.P and King, R.H., "Criteria for Lunar Outpost Excavation," Space Resources Roundtable –SRR IX, October 26, 2007, Golden, Colorado