Characteristics of an Artemis Lunar Construction Modular Toolkit. C. S. Dickinson[1], C. Gregg[2], J. Schuler[3], R. Mukherjee[4], S. Crane[1], J. Empey[1], T. Girgis[1], M. Montano[1], and J. Thangavelautham[5], [1]MDA, 18050 Saturn Ln #200, Houston, TX, [2]NASA Ames Research Center, Moffett Field, CA 94035, [3]Kennedy Space Center, FL 32899, [4]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91101 [5]University of Arizona, 1200 E University Blvd, Tucson, AZ 85721 (Contact: cameron.dickinson@mda.space)

Introduction: Modularity and complementarity are of high value for lunar construction, especially to the early stages of lunar base development. By leveraging the combined capability of many early construction systems, these attributes enable flexibility to meet a wide range of early construction needs in different locations, scalability, maintainability in a harsh environment, and reusability in different locations for economical re-use of down-mass for lunar development. System strengths of each element augments the capabilities of others.

Understanding that lunar construction of early and sustained infrastructure will rely on a variety of construction elements and techniques, we will examine the possible modular and complementary elements of a lunar "toolkit". This is meant to serve as a roadmap to include larger elements of increased complexity, and provides a method for evaluation of different technologies and their deployment. This work will consider the complementarity of the following three elements:

- The NASA AMES ARMADAS construction system [1] - A cuboctahedron truss based general assembly system that can be flat packed for cis-lunar transit, and then robotically assembled and reconfigured into a large variety of configurations.
- The NASA KSC IPEx excavator [2] - A low mass robotic lunar regolith excavator system that can dig, haul, and deposit 10 metric tons of regolith per lunar day.
- The University of Arizona/JPL/MDA LUNAR-BRIC construction system [3] - A reusable regolith filled bag system that can be used for radiation shielding or rocket blast protection.

Module Categorization: The elements are broadly categorized as:

Construction Units being the Toolkit modules that are consumable structural elements. They include the ARMADAS truss voxel (at left) and LUNAR-BRIC Regolith Containment Units (below, right).

Construction Enablers are the elements that are employed to move / place Construction Units or regolith. For the present work, this would be the IPEx excavator (below, left), the ARMADAS construction robot (above), and a manipulator + mobility platform for construction using LUNAR-BRIC (below, right).

Modular Properties: The properties of both the Construction Units and Construction Enablers provide estimates of their deployment resource usage. These include standard items such as power, downmass, and volume but would also include characteristics such as positioning accuracy, traverse speed and carrying capacity.

Complementarity of Modules: With the module functionality and properties established, the complementarity between modules can be assessed. There are a multitude of different ways that this can occur (even with only 3 systems being considered), but generically this will establish standard methods for module interface and co-function. Examples of this include: An interface for IPEx to deliver regolith to the LUNAR-BRIC module for bagging; Interface(s) such that ARMADAS can be employed with LUNAR-BRIC for the purposes of mixed construction and alignment.

Mission Analysis: A digital twin environment with the above parameters would be created to study construction scenarios. Operations can be quickly assessed to minimize their power, downmass usage and build time (for example), while maximizing construction volume. Simple physics models could show the efficacy of radiation or rocket blast shielding.

References: [1] Gregg, C. et al Automated Reconfigurable Mission Adaptive Digital Assembly Systems (ARMADAS), LSIC Spring Meeting (2023) [2] Mueller, R. P. et al. *Design of an Excavation Robot: Regolith Advanced Surface Systems Operations Robot (RASSOR) 2.0.* Earth and Space (2016) [3] Dickinson, C. S. et al., *Construction of Lunar Surface Structures Using Regolith Filled Sandbags*. LSIC Fall meeting (2023).