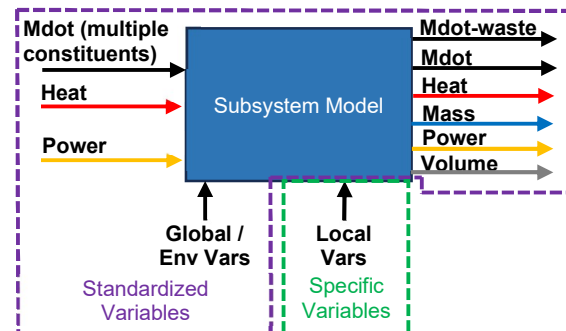


System Engineering & Integration (SE&I) In-Situ Resource Utilization (ISRU) Modeling and Analysis (SIMA) Tool for Subsystem Integration into full-scale Architectures. A. L. Carlson¹, N. L. Andersen¹, and J. Collins² ¹Jacobs Technology/JETSII, 2224 Bay Area Blvd, Houston TX, ²NASA EP3 Branch, 2101 NASA Parkway, Houston TX (Contact: jacob.collins-1@nasa.gov)

Introduction: In situ resource utilization (ISRU) is the practice of producing mission consumables from local lunar/planetary resources, thereby minimizing system launch mass requirements, mainly through the production of propellant fuel components and life support resources. Modeling full ISRU technology architectures significantly impacts the design and optimization of individual unit processes and facilitates their introduction into service with the Science Technology Mission Directorate (STMD) logistical planning and operation space [1]. The Mission Analysis and Integration Tool (MAIT) is a modeling framework that connects individual ISRU subsystem models for the purposes of technology downselect, scaling & optimization, and end-to-end process planning. The development project team seeks to address specific STMD capability gaps by simulating ISRU systems in MAIT. The goal is to produce system architectures for the Moon and Mars that are linked to Key Performance Parameters (KPP) and environmental requirements. To that end, the framework is adaptive, flexible, and suitable for collaboration among government, private sector, and international entities. Our approach currently provides conventional outputs, such as mass, power, and volume, to analyze whole system trade spaces. However, the framework was designed to validate current breadboard subsystems, simulate future process design capacity, and allow flexibility to any external developer-driven subsystem model that is in a state of evolution.

Model Details: MAIT consists of modular elements that read and pass information between individual subsystems (see figure right) forming a larger system process. The modules are able to access files written in multiple software languages, and the “drag-and-drop” data manipulation allows for customizable process flow diagrams according to the desired end user need. The MAIT framework consists of three parts: a user-defined master list of subsystem variables, the process flow environment encoded in Simulink (Mathworks graphical programming suite) [2], and the subsystem model files prepared by technology developers. The modules in the process flow environment contain code that interacts with the subsystem software, pass important information to the model, and ultimately run the model and record the results.



Example Use Case: A lunar water mining architecture is one system process design being considered for the production of propellant [3], where water vapor is sublimated from icy Lunar regolith, and electrolyzed to produce oxygen. MAIT connected all subsystems in the product development path, and coordinated developer models ranging from regolith excavation, particle size sorting, heat transfer and sublimation of water vapor, and finally electrolysis, liquification, and storage. Several production targets were investigated including a 1, 10, & 50 metric ton architecture. At the time of this abstract, the parametric runs are still in process and the data is being analyzed. The results will show optimal mass, power, and volume correlated to the dimensions (screw diameter and length) and heater setpoint in the Lunar auger dryer (LADI) subsystem. Another parametric study on the same system model includes trading the Solid Oxide Electrolysis (SOE) versus Proton Exchange Membrane (PEM) downstream subsystems. Preliminary results indicate that further decreases in power demand could be realized with modifications to proton conduction in the electrolysis unit.

Future Work: In addition to improving MAIT's core processing ability, numerous ISRU architectures are expected to be developed. In the short term, there are plans to investigate Molten Regolith Extraction (MRE) technologies and Mars propellant production.

References:

- [1] NASA Space Technology Directorate (2023). *LIVE: In Situ Resource Utilization (ISRU)*.
- [2] Mathworks (2023) *Model-Based Design for Embedded Control Systems*. [3] Collins J. (2023) *Lunar Water Extraction via Lunar Auger Dryer ISRU (LADI)*. ASCEND 2023, 2023-4078.