LUNAR WATER EXTRACTION via LUNAR AUGER DRYER ISRU (LADI).

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Introduction: In 2009, the Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (LCROSS) provided definitive proof of water in the Lunar's southern permanently shadowed region (PSR)[1]. Both the 2020 NASA Technology Taxonomy[2] and the Lunar Surface Innovation Initiative (LSII) team identified capability gaps in icy regolith transfer and reactor processing in Permanently Shadowed Region (PSR) environmental conditions. A water processing plant operating from inside the PSR can continuously process water (and volatiles) for both breathable air and propellant. NASA's Johnson Space Center (JSC) began development of the primary sub-system for a Mars plant in 2017 and fabricated a unique breadboard test stand for validating the feasibility of this concept. This testing was postponed with the redirection of NASA's mission from Mars to Moon. A JSC led trade study[3] in FY20 formulated a plan to leverage existing hardware to test concept feasibility, developed a lunar auger dryer sizing tool, and identified that both physical flow and thermal models are required to develop an Engineering Development Unit (EDU) for environmental testing.

The major subsystems of a lunar water processing plant include a.) an upstream excavation rover and a hopper/size-sorter, b.) an auger dryer, and c.) a downstream cold trap used for ice deposition (water vapor to ice). The top-level concept of operations begins with the excavator digging up icy regolith and delivering it to a stationary ISRU processing plant (inside PSR), size sorting the feed to remove large rocks, and then discharging into a hopper. The hopper feeds the regolith to an auger-dryer which extracts water from the soil and then sends it to a cold trap subsystem. The dried regolith is collected, dumped (potentially processed for waste heat), and the excavator repeats the process. Ice deposition occurs in the cold trap as vapor is converted into ice, impurities removed, and the product stored on a tanker. This tanker will either travel out of the PSR to a stationary electrolyzing processing plant located on the crater ridge or the tank will be pressurized, and liquid water pumped to the plant via flex hose. At the crater ridge, the water is cleaned, electrolyzed into oxygen and hydrogen, liquefied, and finally stored.

The key design features of the auger dryer design is operating below the triple point of water and using a variable pitch auger to create a 100% full regolith plug-seal at the inlet and outlet of the auger with a 15% full heated section. These features maintain low internal pressure (easier to sustain regolith plug), prevent liquid water (increases motor torque and initiates equilibrium chemistry with impurities), and eliminate the need for isolation valves. Isolation valves increase system height, mass, complexity, and reduces reliability.

The breadboard auger dryer, shown in Figure 1, has the unique capability to operate with either a clear or stainless-steel casing supporting both mechanical and thermal test requirements. The test stand was setup in JSC's dust containment test cell.

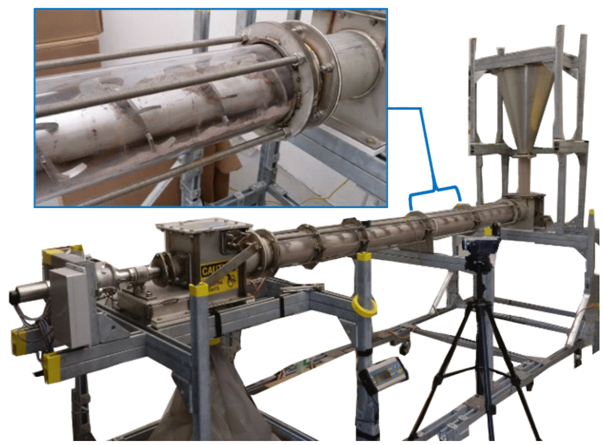

Figure 1 – LADI Breadboard (clear casing installed)

Nineteen mechanical and multiple thermal test runs were completed using Exolith Lab's Lunar Highlands Simulant (LHS-1) increasing the breadboard system to TRL 4. Five unique auger geometries, shown in Figure 2, and three motors configurations were used to optimize steady state flow. Torque, RPM, mass flow rate, gate angle, and power were measured while observing discharge plug behavior.

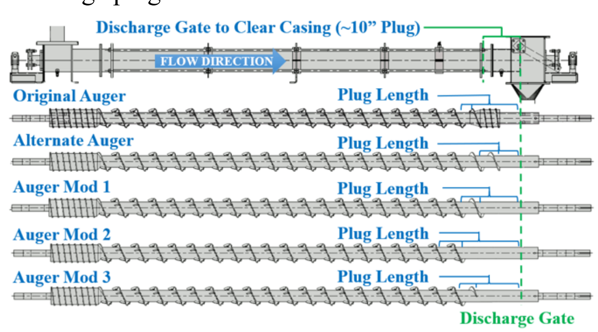

Figure 2 – Auger Configurations Tested

[1] A. Colaprete et al. (2010) *Detection of Water in the LCROSS Ejecta Plume, Science, Vol 330*. [2] D. Terrier (2020) *NASA Technology Taxonomy*, *NASA*. [3] J. Collins and L. R. Erickson (2021) *Lunar Auger Dryer ISRU (LADI) FY20 Formulation Report, JSC-67579 Internal Note.*