In-Situ Synthesis of Propellants and 3D Printed Materials from Lunar Regolith. A. D. Whizin[1], U. Raut[1], K. Retherford[1], M. Miller[1], V. Poenitzsch[1], K. Kirkpatrick[2], and H. Shin[3], [1]Southwest Research Institute (Akbar.Whizin@swri.org), [2]RedWorks, LLC, [3]Korea Institute of Civil Engineering and building Technology.

Introduction: In order to enable operations and long-term human and robotic presence on the lunar surface, our ISRU *Synthesis* work advances the science and technology required for scalable production of locally-sourced building materials as well as propellants and volatile products from raw lunar feedstocks. The goals of this work are: 1) to study the feasibility and scalability of additive manufacturing (AM) at various locations on the lunar surface; 2) the production of volatile products; 3) the advancement of ISRU 3D printing and heat-print-release capture (HPRC) cryotrap technology; and 4) the operational demonstrations of developed hardware under environmental conditions. We specifically target the following investigations: (i) plasma synthesis of propellants and cohesive polymer binders from lunar volatiles; (ii) additive manufacturing methods of sintered, molten, and polymer-bonded regolith structures; (iii) characterize material and mechanical properties of the end products; (iv) characterize radiation and heat shielding properties of bricks for astronaut shielding.

Production of Fuels and Polymers: A component of a solid rocket propellant composed of an extended heterocyclic structure can be synthesized via reactive plasma processes, starting from carbon monoxide as a low-cost gaseous feedstock (Figure 1). Here at SwRI we will assess what reaction pathways can lead to the synthesis of useful products that can be efficiently accessed from the available volatile species on the Moon and then synthesize key chemical intermediates, gas-phase oxygen, synfuels, solid propellants, and polymers from reactive plasma processes based on RF and high-power DC impulse excitation.

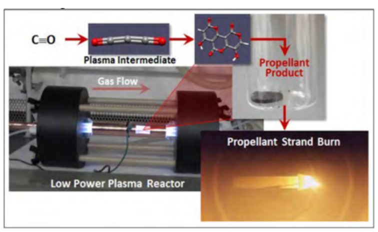

Figure 1. Discharge reactor for low-power plasma-based synthesis of a potential solid organic/inorganic propellants enabled by formation of intermediates leading to potential solid propellants like C_3O_2 and $[H_2Si\text{-}NH]_n$.

Additive Manufacturing on the Lunar Surface: We are starting a detailed investigation into two AM methods, designing a new type of AM volatile capture system and advancing its TRL, as well as build an environmental chamber to test and host ISRU technology demonstrations of the HPRC, AM, and numerous hardware modules emerging from other ISRU research conducted. We'll explore magnetic induction and polymer binders, as well as microwave sintering with our Korean collaborators. They will utilize nanophase iron in their simulant KLS-1. Nanophase iron drastically increases the effectiveness of microwave sintering, previous work has been lacking in this critical element of thermal sintering catalyst.

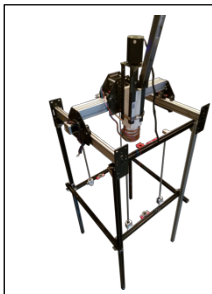

Figure 2: Red-Works 3D printer prototype.

Additive construction by cohesive binders offers an enticing alternative to sintering or molten extrusion, especially if the binders can be produced in-situ from excavated volatiles, therefore we are working on the development of highly ordered polymers in structured materials, and the application of these polymers as binders to strengthen and mold lunar regolith.

Magnetic induction (MI) heating, which can save on cost and power, heats conductive metals through heat generated in the feedstock by eddy currents. We have partnered with RedWorks, LLC and are currently utilizing their (TRL 3) 3D print system (Figure 2) to explore lunar ISRU applications, including radiation shielding to protect astronauts.

The energy inputs for ISRU and AM on the lunar surface may require robust and efficient power systems, but the combination of the synergistic ISRU subsystems can be intertwined to save substantial energy savings. RedWorks' 3D print head will be modified to capture off-gassing volatiles and cold trap them in in the HPRC system. A HV chamber will capture the sublimating volatiles in a cryo-cooled cold trap released from lunar regolith simulants such as H_2O, CO, H_2S, NH_3,O_2, SO_2, CO_2, and H_2 (Figure 3).

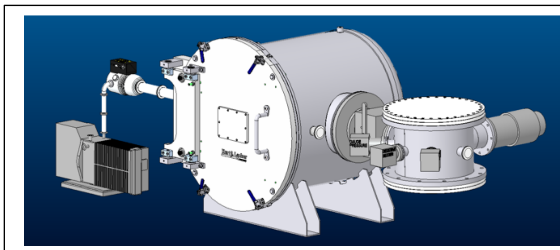

Figure 3: Preliminary design of the HV chamber.