Maturing Aluminum Production from Lunar Regolith: Status of the MAGMA Project. K. M. Cannon[1], C. B. Dreyer[1], A. Ignatiev[2], G. L. Brennecka[1], C. Brice[1], J. Kim[1], Z. Yu[1] and the MAGMA team, [1]Colorado School of Mines, 1500 Illinois St., Golden, CO 80401, [2]Lunar Resources Inc., 6721 Portwest Dr., Houston, TX 77024. Email: cannon@mines.edu

Introduction: The MAGMA project (Molten Aluminum Generation for Manufacturing Additively) is a LuSTR23 selection to mature technology for extracting aluminum from regolith at the lunar south pole and turning it into an additive manufacturing feedstock. Previous work on high-temperature regolith processing focused on oxygen as the main product or looked at iron and titanium that would be extracted from mare regolith at equatorial landing sites. With the current goal of building up infrastructure at the lunar south pole in highlands terrains, aluminum is a much more viable metal and has diverse applications in power transmission, radiators, and structures like towers. Here, we provide an update on the current project status and future plans.

MAGMA Overview: MAGMA is being led by Colorado School of Mines with Lunar Resources as the sole industry partner. The team has expertise in lunar geology, ISRU hardware, metallurgy, materials science, and additive manufacturing. The main technology being pursued is Molten Regolith Electrolysis (MRE), which operates directly on raw regolith of any composition without the need for an electrolyte or other consumables shipped from Earth. The overall goal of the project is to work toward an integrated test in vacuum that produces pure aluminum from highlands regolith simulant and casts it into a wire that would be appropriate for additive manufacturing applications. The work is broken up into sub-tasks as described below.

MRE Reactor and Wire Casting: Lunar Resources is providing the MRE reactor based on past work that has demonstrated aluminum production at the benchtop scale. An approximately one-meter diameter system will be used and throughout the project we will switch from operating in air to operating in vacuum as part of the TRL maturation.

Additionally, Lunar Resources is developing a new casting system as part of this project to transform the molten aluminum tapped out of the reactor into a wire feedstock. The casting system is currently in the early design phase.

Tap/Launder System: Multiple taps and launders are needed to move molten products to different parts of the system and ultimately to expel final products (metals) and residual slag from the reactor. So far, we have done preliminary work to understand the viscosity and flow conditions of the metals and slags, which will feed into the tap/launder design options. We are also canvassing taps used in foundries. The next steps are to carry out a system requirements review for the taps/launders and move forward with multiple design options that will be prototyped and tested with room-temperature fluids of representative viscosity.

Materials Compatibility: The tap/launder hardware will come into contact with high-temperature (1600–2000 °C) liquids including metals and oxide slags. This presents a materials compatibility challenge including withstanding high temperatures, keeping strength at those temperatures, limiting corrosion, and limiting wettability. We have identified a set of candidate materials including alumina, graphite, silicon carbide, boron nitride, zirconia, and SiAlONs. Current lab experiments are measuring wetting angles and corrosion of these candidates with synthetic versions of the molten regolith and metal/slag products.

Computational Thermodynamic Modeling: The phase equilibria at different steps of the MRE process will determine which products form, how they will behave in the reactor, and the expected purity of the final metal products. We are using FactSage to model the thermodynamics of the system and have started by tracing out the compositions of the two regolith simulants we plan to use in the project as they are chemically reduced. Later work will explore a broader range of compositions from lunar data that represent likely southern polar regolith.

Aluminum Wire Evaluation: The project will result in cast aluminum wire intended for additive manufacturing. The properties and quality of the wire are important to characterize and potentially improve by modifying the MRE process. We intend to measure grain structure, defect size, chemical composition, and drawability of the wire product. Early work will carry out these measurements on off the shelf aluminum wire to serve as a baseline; when wire is available from the casting process we will characterize it with the same techniques, and ultimately will do the same for the end-to-end demo working from regolith simulant to wire.