Manufacturing and Metal Extraction Lunar Technology (MMELT)

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Abstract:

The goal of this study is to demonstrate the first end-to-end process to additively manufacture aluminum derived from lunar regolith simulant in a relevant environment. This will be accomplished by refining the aluminum metal produced by carbothermal reduction and molten electrolysis and printing this using a Directed Energy Deposition (DED) additive manufacturing process under vacuum.

State of the Art

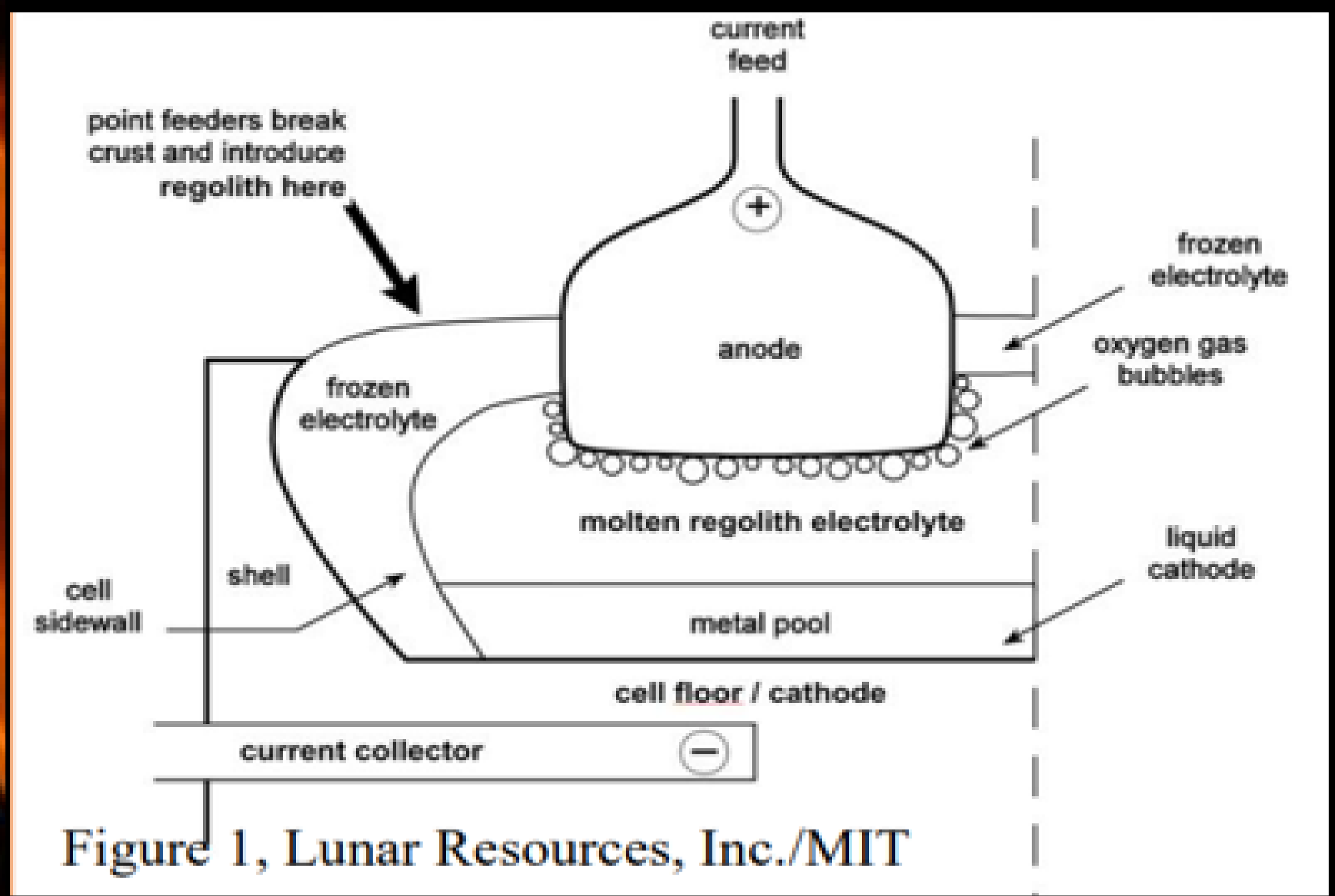


Figure 1: Diagram of molten regolith electrolysis under development by Lunar Resources Inc.

Figure 2: Sierra Space, Corp carbothermal reactor inside the vacuum chamber at JSC (photo source: nasa.gov)

Extraction processes of oxygen from regolith under development include carbothermal, molten regolith electrolysis (MRE), ionic liquids, and others, all of which result in a metal slag byproduct. The separation of some of these metals from the slag byproduct have been accomplished on small scales. However, no system currently exists that can extract aluminum, from these processes at scale, to create suitable feedstocks for manufacturing.

Funding for MMELT will be used to develop a demonstration of the first end-to-end process to additively manufacture aluminum wire from lunar regolith in a simulated environment.

MMELT Develops

Task Elements 1 and 2: Aluminum Refining

Figure 3: Aluminum wire; desired product of MMELT

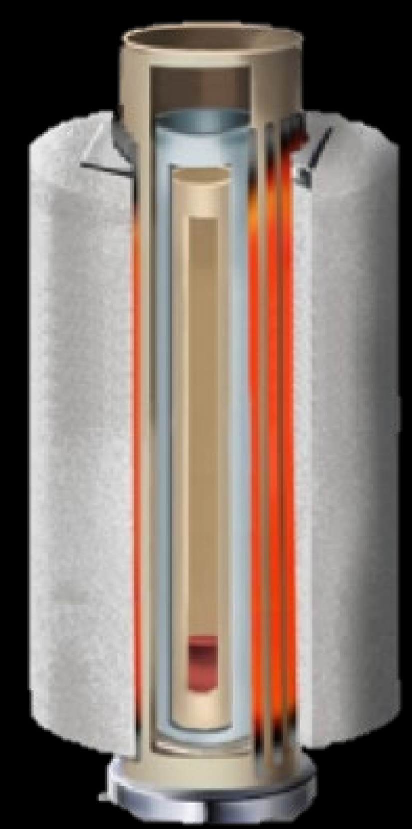


Figure 5: Conceptual Lunar surface vacuum distillation-based aluminum refiner.

Task Element 3: Truss AM Process Development

Figure 4: Axis Robotic Arm in Building 4707

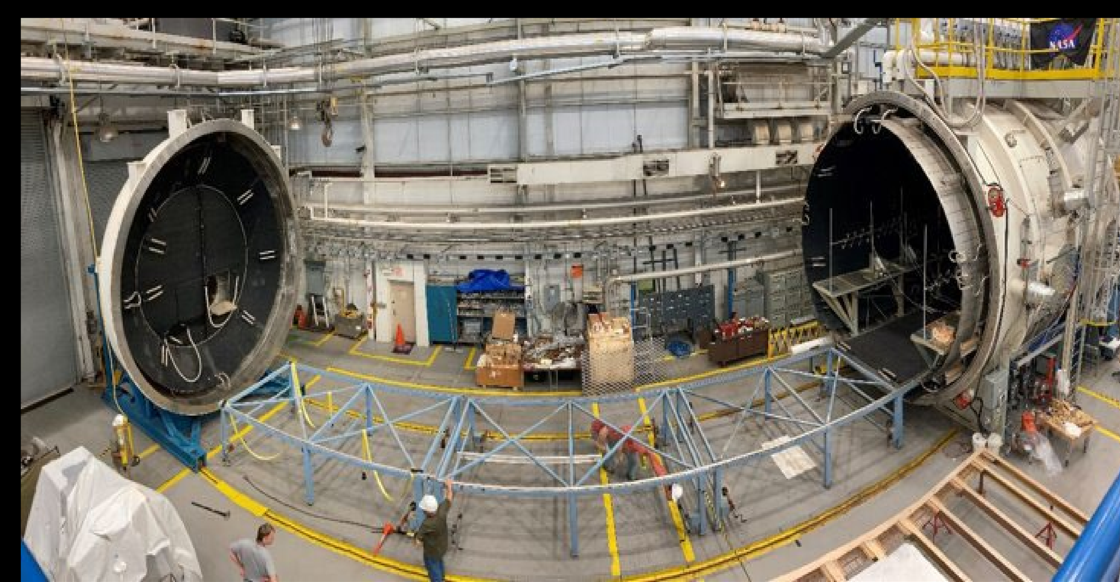
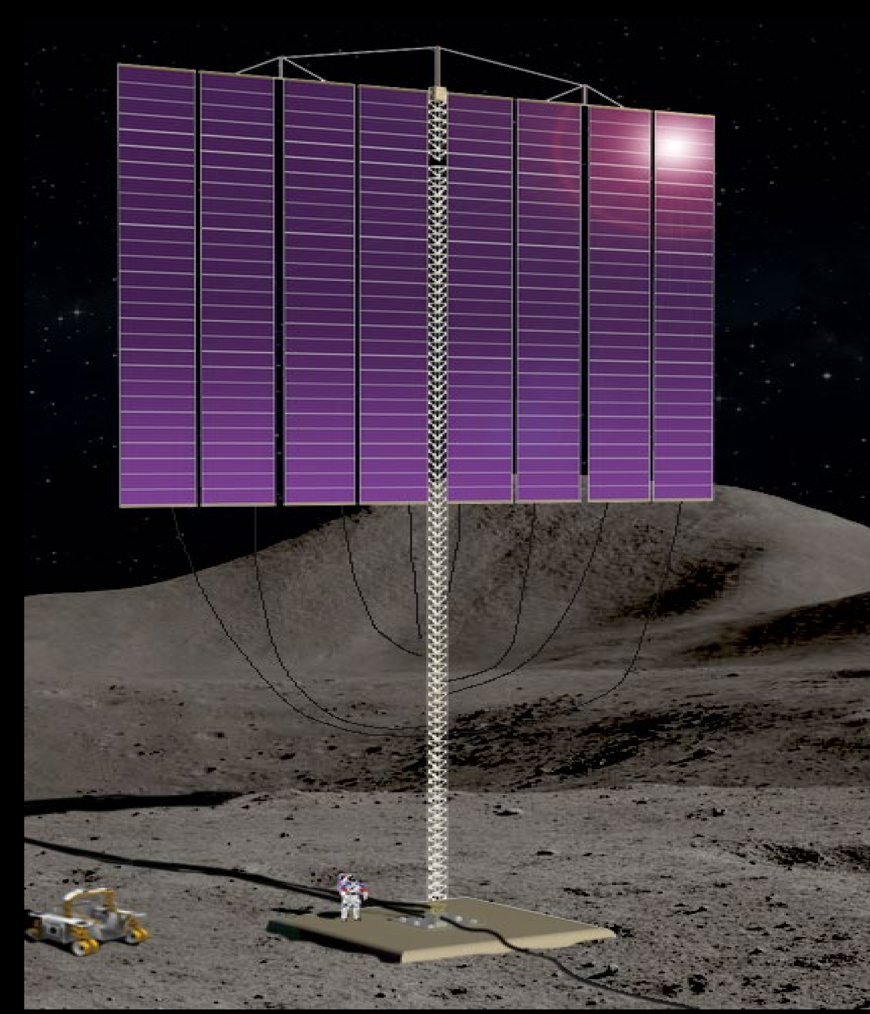


Figure 6: MSFC V20 Lunar regolith rated thermal vacuum chamber where truss demonstration articles are to be printed

Lunar Resources, Inc. developed a proprietary MRE-based process to produce aluminum. This project will utilize aluminum wire extruded from their MRE reactor as one of the precursors for the manufacturing process. An aluminum refining technology for the carbothermal reduction slag will be developed at MSFC in collaboration with Sierra Space. Sierra Space will provide the carbothermal slag which will be refined using a vacuum distillation technology under development at MSFC. The ISRU-derived aluminum feedstock from both processes will be evaluated for additive manufacturing of truss structures. The additive manufacturing process will be developed and optimized at MSFC, leveraging capability and facilities including directed energy deposition robotic arm and V20 vacuum chamber for relevant environmental testing. The manufacturing process will enable the production of truss structures for the construction of a realistic tall tower demonstrations in the 2030's and beyond

MMELT Enables



Delivering 1 200kg truss tower to the lunar surface costs $240M alone in payload mass.

ISRU based manufacturing is the economically viable pathway for sustainable Lunar infrastructure.

Figure 7: Notional 200 kWe solar power module. (Matt Mehlin, Polaris TLT Project)

Figure 8: Shelter concept (Lunar Safe Haven seedling study)

A 50-meter tower supporting a 50kW solar array for power architecture is estimated to require ~200 kg of aluminum for building truss elements. Looking at target power requirements for a lunar outpost, this would require over 3,000 tons of material to be delivered to the lunar surface to reach the estimated ~7.8×10^5 kW target value [*Optimal Sizing and Siting of PV and Battery Based Space Microgrids Near the Moon's Shackleton Crater, Diptish Saha, et al*]. A lunar truss tower provides a direct path to the use of ISRU-based structural elements (e.g., aluminum truss members) and will enable sustainable construction of power infrastructure. The proposed technology is applicable to the construction of other large-scale infrastructure elements such as storage tanks for ISRU needs, blast containment shields, sunshades for propellant depots, and protective shelters.