SMELT: Smelting with Microwave Energy for Lunar Technologies

Team Members (Leads Underlined): Alex Baumgartle, Avimukta Dokuparthi, Chiranjeev Singh, Colton Washburn, Craig Oluoch, James Connelly, Jason Oh, Jack Pierce, Marisa Tommarello, Patrick Moore, and Samuel Highfield
University Advisors: Dr. Sven Bilén and Dr. Aleksandra Radlińska
Sponsors and Other Advisors: RFHIC and Michael Fiske

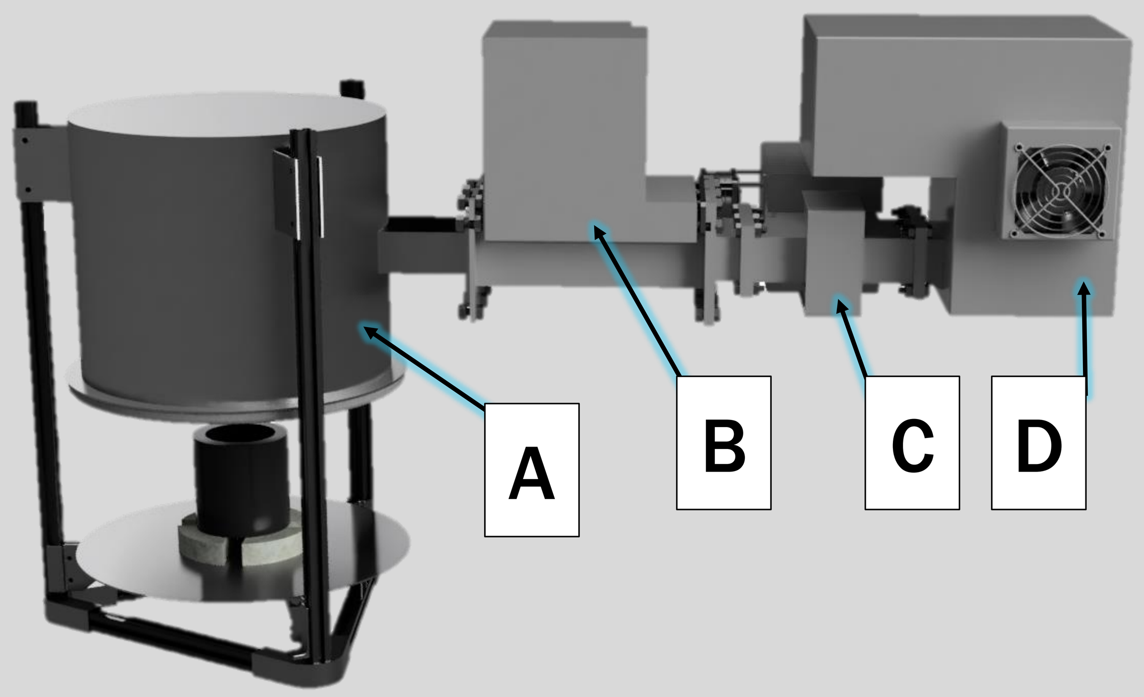
Abstract

The SMELT system is a novel solution to the *smelting and other metal reduction method* component of the lunar product lifecycle. Microwave power is an efficient heating solution that can work in the cold, vacuum environment of the lunar surface. The design of SMELT is flexible enough to be scalable, as energy efficiency has not been observed to reduce as the material load inside the crucible increases. SMELT fits into a larger system of systems of microwave usage on the Moon.

Concept of Operation

1. Crucible is loaded with payload of prepared *in-situ* material
2. Crucible is positioned within ceramic fiber insulation casing
3. Conveyance system lifts insulation casing assembly into microwave resonance chamber
4. System preforms a heating cycle determined by type and amount of material to be melted
5. Conveyance system removes insulation casing assembly from microwave resonance chamber
6. Molten material is moved to other devices for further processing

SMELT Design



A. Microwave cavity attached to material conveyance system
B. Daihen SMA-15B tuner
C. WR340 Isolator
D. 1.5-kW magnetron connected to an Automatic Microwave Tuning Control Unit

Crucible & Insulation

- Silicon carbide (SiC) crucible rapidly heats via microwaves
- Alumina coating prevents molten material from reacting with SiC
- Ceramic fiber insulation retains heat in an atmospheric environment

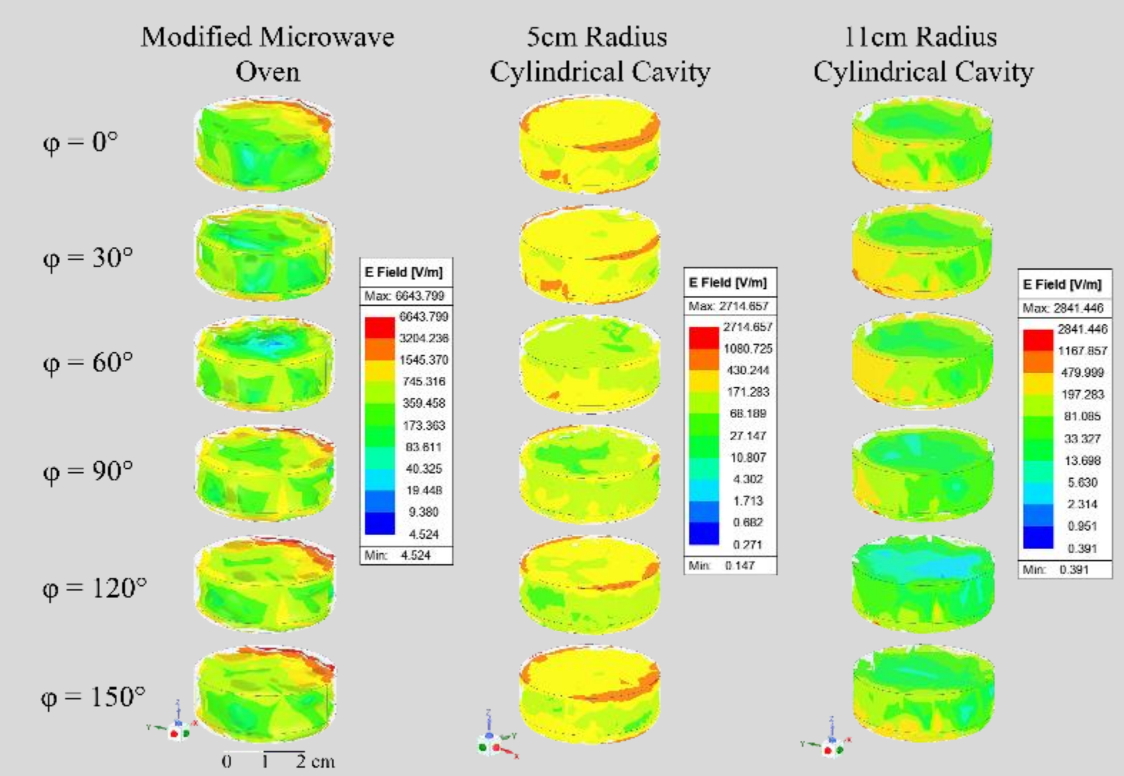
Future Adaptations

- 900-MHz power for larger chambers
- Microwave leakage detection integrated into control system
- 6-kW solid-state microwave source

Research Innovations

- Microwave heating application for lunar *in-situ* resource utilization
- Creation process to rapidly produce crucibles of various sizes
- Lightweight, compact, and power-flexible heating source

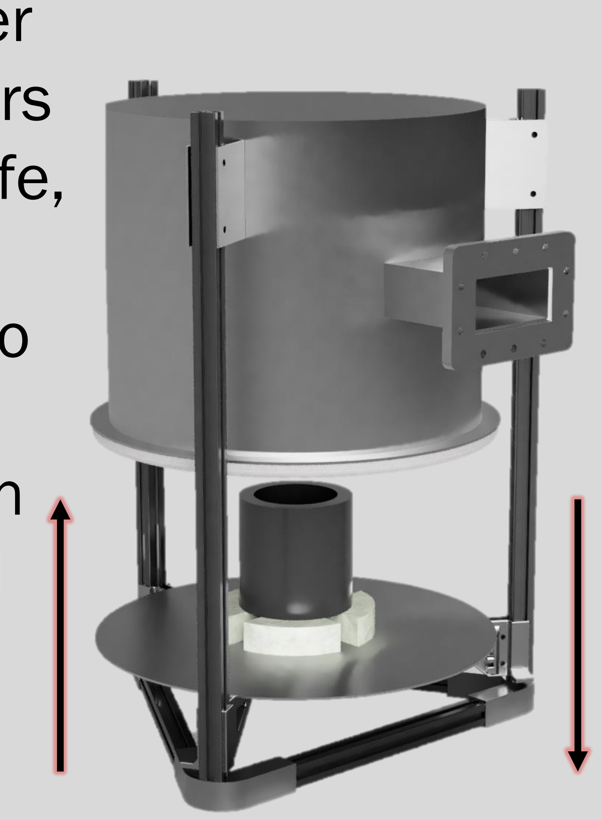
ANSYS Simulation



ANSYS HFSS was utilized by SMELT team to optimize resonance chamber. Simulations determined necessary size, shape, and materials for chamber to focus maximum energy on centrally located crucible.

Conveyance System

A belt-driven chamber floor raises and lowers to allow for quick, safe, and remotely controllable access to the resonance chamber. System can be further developed to directly interface with additional processing systems.

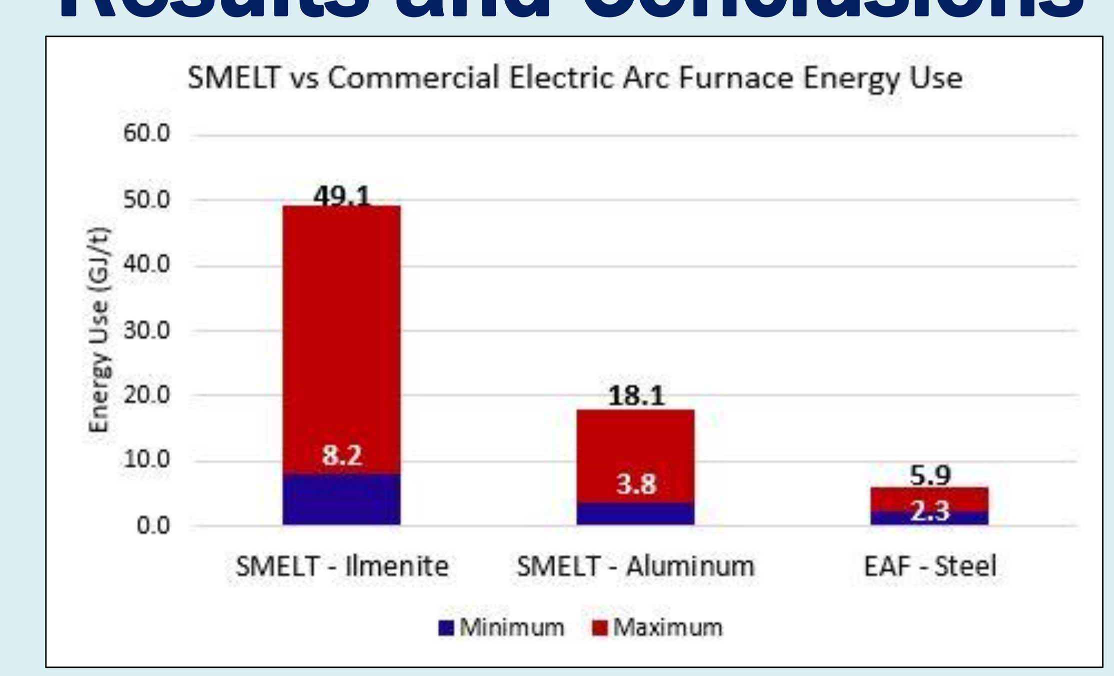


Verification Testing on Earth

Variables tested during experimentation to determine energy efficiency through maximum temperature measurements:

- Cycle Time
- Cycle Power
- Material Type and Quantity (Ilmenite or Aluminum, 20 g and 125 g)

Results and Conclusions



Experimental results provided the following conclusions:

- Comparable energy requirements to commercial electric arc furnaces
- Positive correlation between energy efficiency and larger scale
- Ability to predict required cycle times to achieve melts based on material, power level, and ambient temperature