



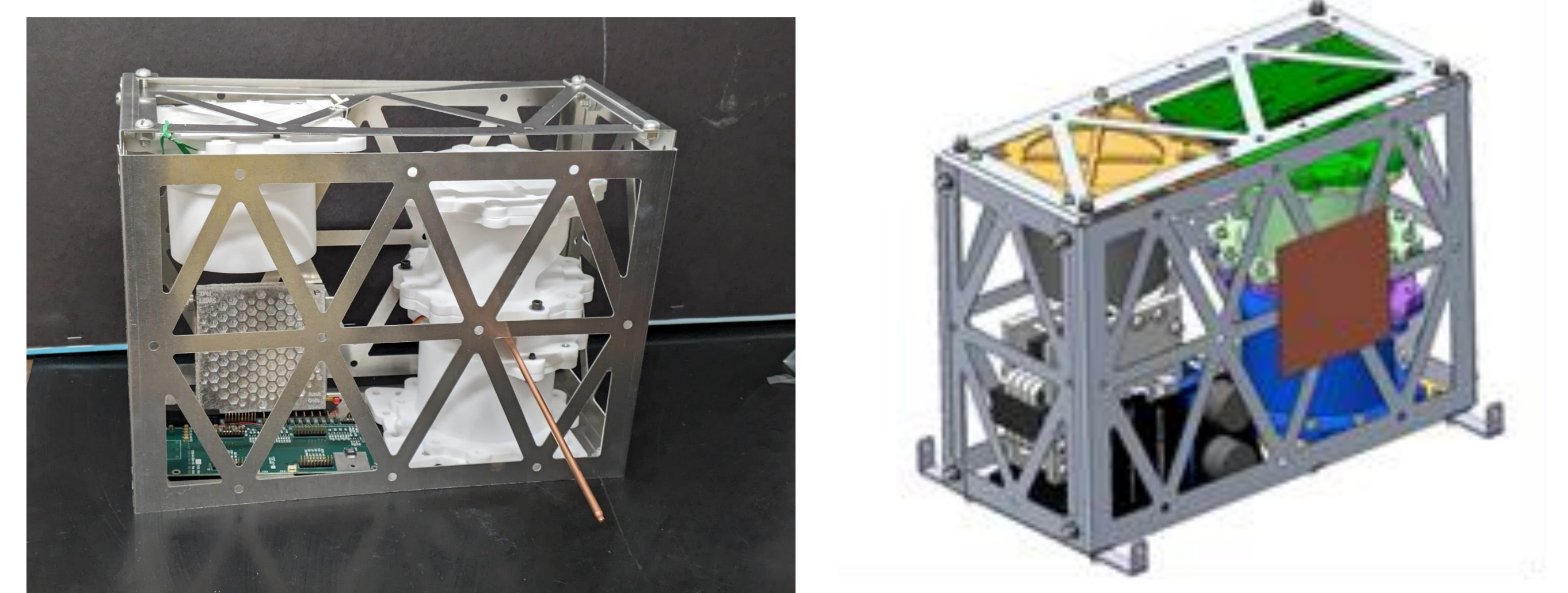
Metal Oxidation Heating – Enabling A Closed-loop Lunar Economic Cycle

ASTROBOTIC TECHNOLOGY, INC.

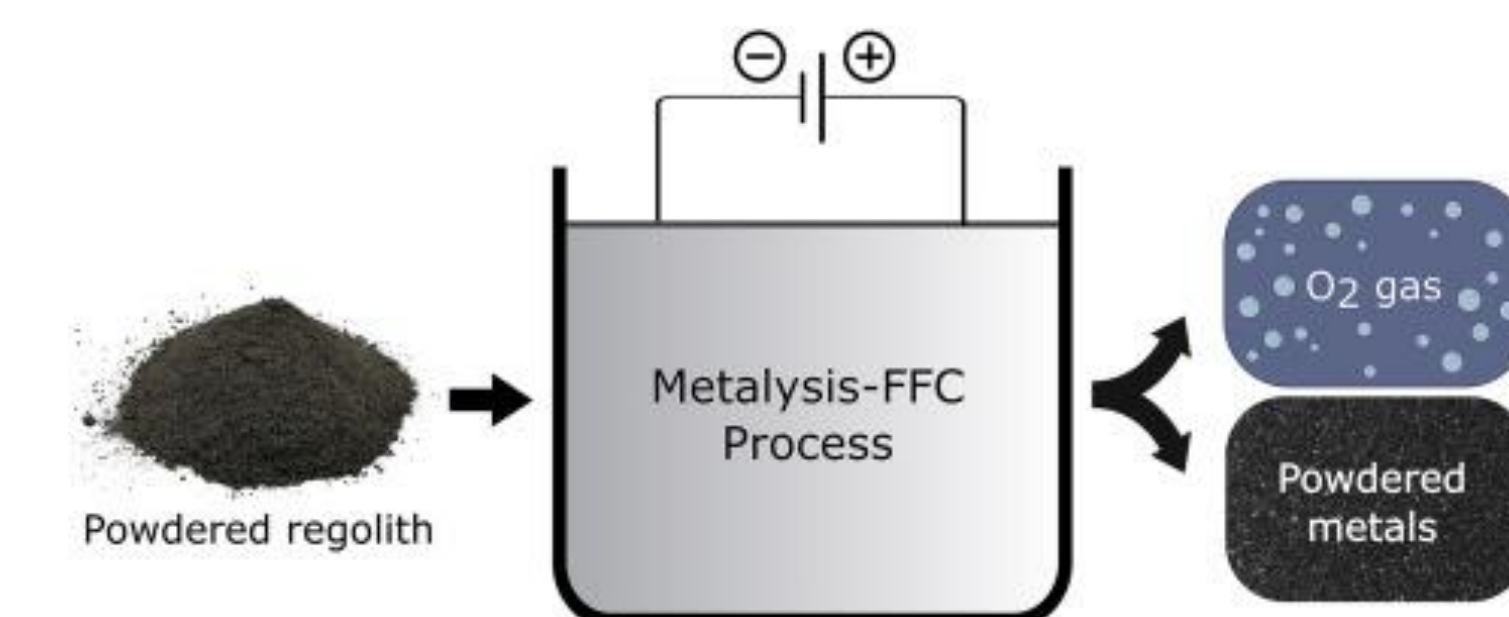
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1. Closed loop concept

- By developing a technology which provides value to the lunar ecosystem, but which also relies on purchasing ISRU derived inputs and selling outputs valuable to other ISRU technologies, Astrobotic feels it can serve as both supplier and customer to other ISRU technologies while providing valuable output to lunar missions and thus enabling a small but critical self-sustaining economic cycle.
- Astrobotic's metal-oxidation based lunar night survival heater, the Nighttime Integrated Thermal and Electricity (NITE) system is this central technology. It runs on a metal-based fuel which can be produced by purchasing unrefined mix-metal slag from Carbothermal Reduction or Molten Regolith Electrolysis (MRE) processes. For oxidizer, NITE can use low concentration hydrogen peroxide developed as a byproduct of lunar ice-based hydrogen-oxygen propellant production, or even by purchasing lunar-mined-ice and carbothermal or MRE produced oxygen and processing its own hydrogen peroxide.
- They value-add output from the NITE system is heat and electricity, which can be used for a variety of applications on the moon. The waste products from NITE are metal oxides and hydroxides; the oxides may be sold back to an oxygen extraction provider as high purity feed stock, while the metal hydroxides are a key component in the production of lunar geopolymers for surface construction and landing pads.
- The closed loop found in this cycle incorporates a number of different suppliers and consumers, who each add value to the economic cycle at each step. By acting as a central buyer and seller for lunar resources, the NITE system can enable a self-sustaining economic cycle between lunar ISRU producers which can eventually scale to include other buyers and sellers not imagined here, and who themselves can add even more value to this ecosystem, enabled by technology but driven by economic forces.



MOWS/NITE unit during assembly for TLR6 testing (left) and render of fully assembled unit (right)



Carbothermal reduction hardware from Sierra Space (CaRD) and molten regolith electrolysis diagram

2. Required Technologies

• Sources

- Bulk regolith extraction
 - Provides feed stock to oxygen extraction, and is the raw source of metal atoms and oxygen atoms for the loop.
- Lunar water extraction
 - The water is source agnostic, but would presumably be from lunar ice. This is the source of the hydrogen atoms and oxygen atoms for the hydrogen peroxide used the fuel cell as well as the propellant.

• Intermediate processes

- MOWS
 - A metal oxidation heating system.
- NITE
 - A direct-liquid fuel cell using dilute peroxide and hydrogen
- Oxygen from regolith
 - Could be any form of extraction (electrolysis, carbothermal reduction, etc)
- Water electrolysis
 - Only used for propellant production
- Low strength Hydrogen Peroxide Synthesis
 - Already demonstrated at TRL 9 on the ISS

• Sinks

- Lunar propellant depot
 - Hydrolox fuel assumed
- Surface construction geopolymers
 - hydroxides used to catalyze geopolymer formation

