Measured Ablation Rates From Ablative Arc Mining

Multiple element extraction from the Moon, Mars, or Asteroids

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Ablative Arc Mining

The ablative arc mining system [1,2] is a technology that can be used on the Moon, Mars, or asteroids to extract elements from regolith. The system uses a plasma arc incited across the regolith surface in combination with electromagnetic fields to bypass challenges related to excavating dusty regolith and rarefied flow environments.

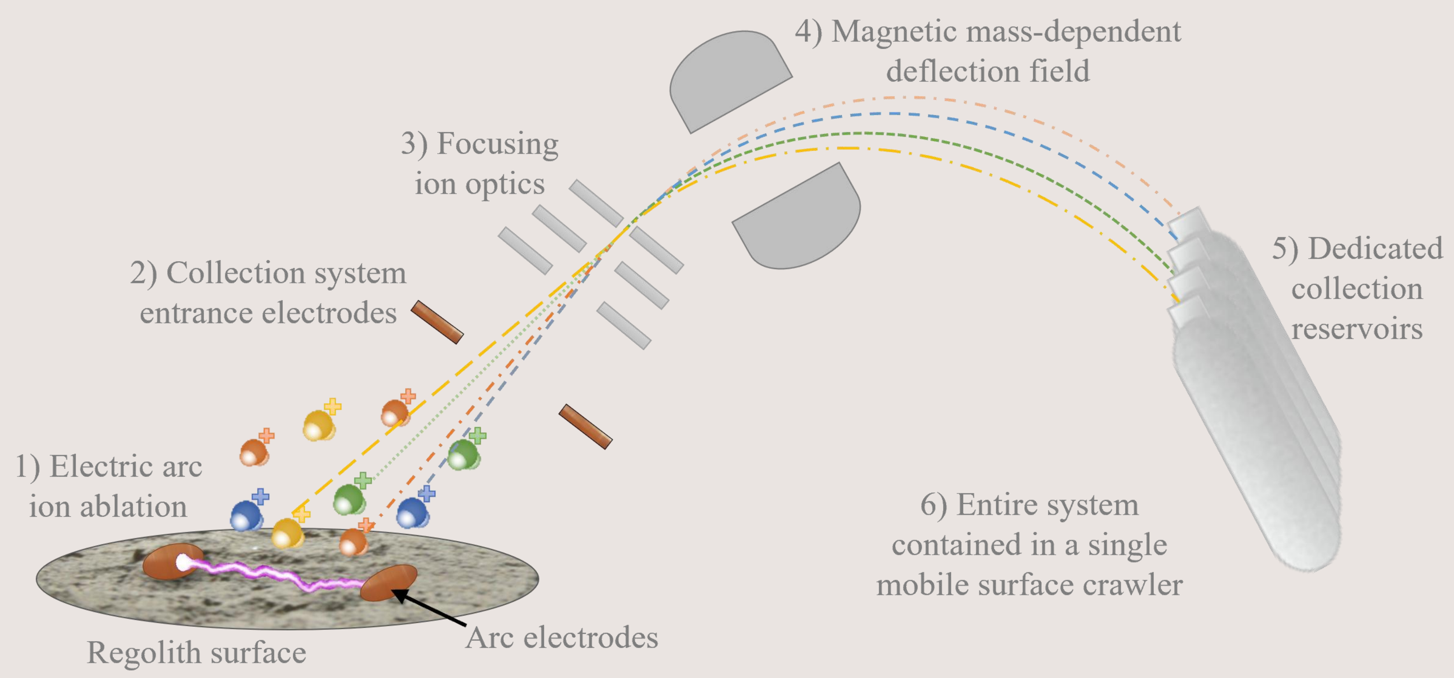


Figure 1: Ablative arc mining system components and concept

1) Two electrodes are placed on the surface of the regolith. An applied high-voltage incites a plasma arc across the surface. The energy of the arc ablates and ionized the regolith into charged ions.

2) The ions are controlled using electromagnetic fields that do not require any minimum back-ground pressure into a collector unit.
3) The ions are focused into a collimated beam using ion optics for uniform velocity profiles.
4) The ions are separated by mass through magnetic deflection, similar in principal to a mass spectrometer.
5) Dedicated collection reservoirs are placed in the path of the respective ion beams to collect and store each material.
6) The system is compact, fitting on a single, mobile vehicle.

A single unit extracts metals and volatiles from any regolith type.

The experiments were performed at The University of Texas El Paso as part of a 2021 NIAC Phase I award.

Measured Ablation Rates

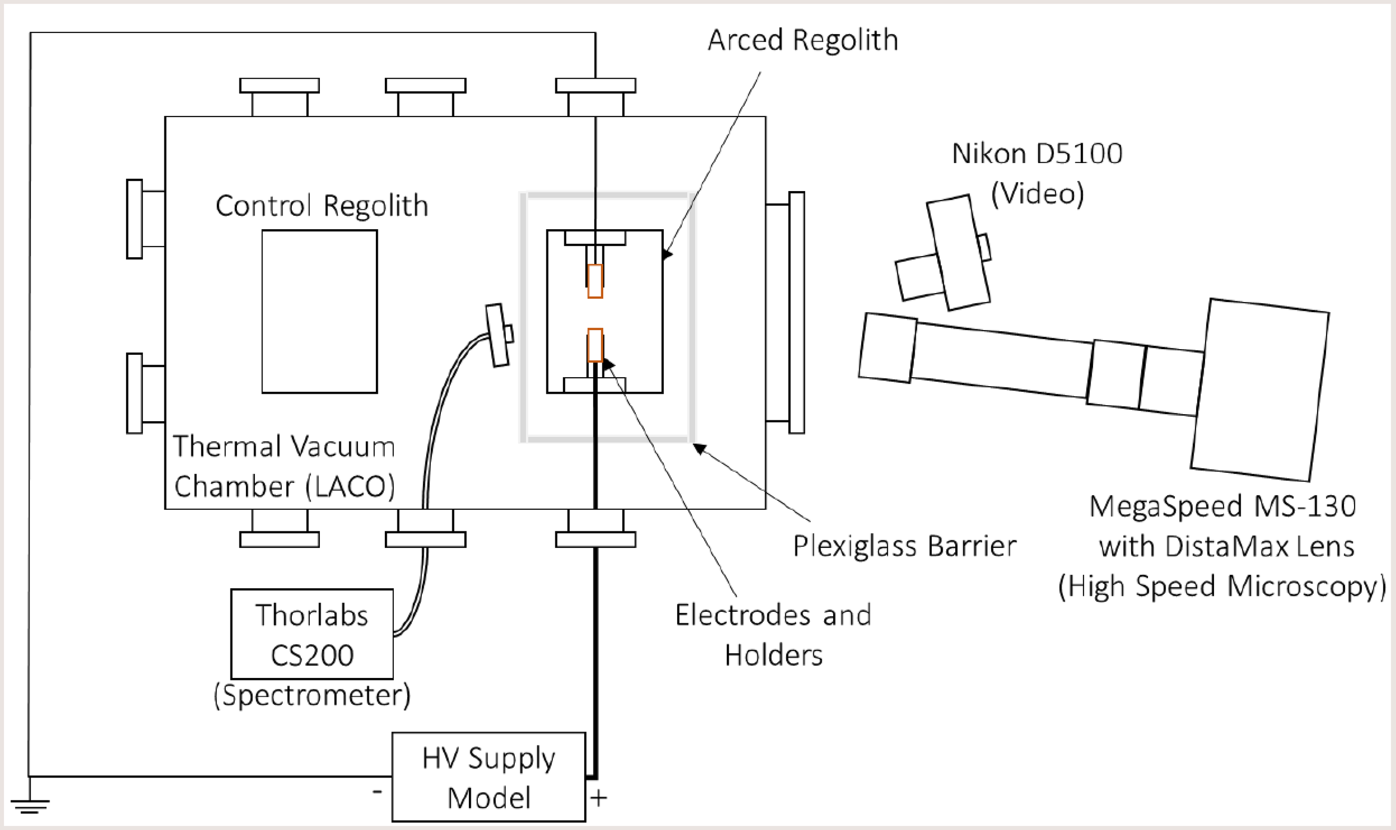


Figure 2: Thermal vacuum chamber setup for ablation experiments.

Initial experiments measured ablation rates inside a thermal vacuum chamber. Arcs were incited between two copper electrodes using a 22.5kV power supply pulsed at 1 Hz for 20 minutes. A second identical regolith box (control) was placed in the rear of the chamber to observe changes from ambient effects. The resulting ablation craters were measured with calipers to determine the total volume of regolith ablated, from which mass loss was inferred from regolith density.

Table 1: Ablation experiment results for 20 minutes at 1 Hz and 22.5 kV

	Ablated Volume (cm^3)	Ablated Mass (g)	Ablation Rate (kg/kWh)	Extrapolated* Yearly Mass (kg)
LHS (dry)	2.27	2.95	0.24	840
LHS (1.8% H_2O)	8.82	11.47	0.92	3200
LHS (5.7% H_2O)	4.08	5.31	0.42	1470
Mars MGS-1	1.77	2.31	0.18	630
CI Asteroid	5.41	5.95	0.48	1680

** Extrapolated yearly values assume 1 metric tonne and 2.5 kW vehicle*

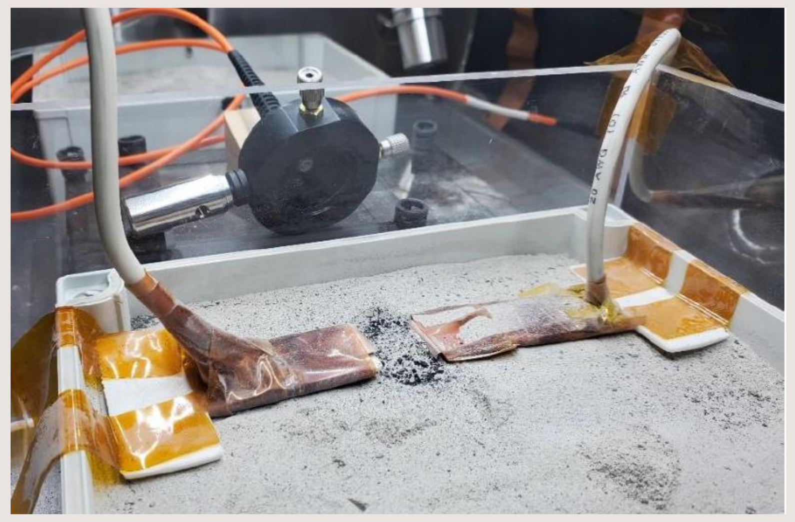


Figure 3: Ablated crater between electrodes after 20 minutes at 1 Hz and 22.5 kV for LHS-1

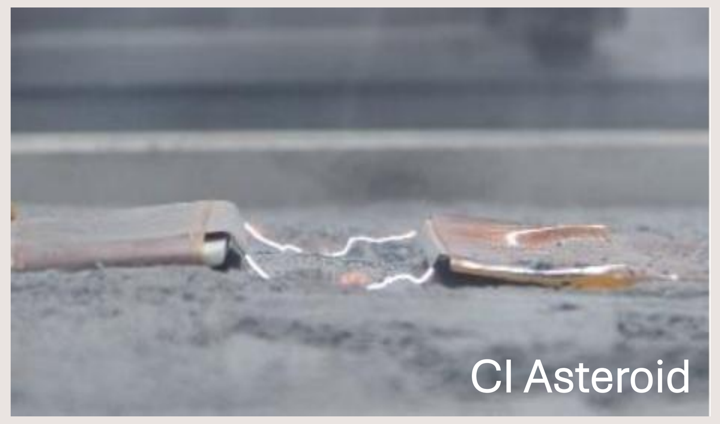
[1] Greig, A., (2022), Earth and Space Proc., 243–254.
[2] Greig, A., (2022) NIAC Phase I Report, NASA
[3] Sanders, G. et al., (2019) Lunar ISRU Workshop
[4] Sowers, G, Dreyer, C., and Williams, H., (2020) NIAC Phase I Report, NASA
[5] Schreiner, S, et al. (2015) , 8th Symposium on Space Resource Utilization

Example Use Cases

Moon – highlands, mare, permanently shadowed regions (beamed power or nuclear); Mars – surface regolith; Asteroids; Earth – mine tailings, frack water evaporite (not yet tested directly)

LHS-1 (dry)

LHS-1 (2% H_2O)



CI Asteroid

Mars MGS-1

Recommendations for Future Work

- Expand ablation experiment to determine the ratios of ablated materials from each material type.
- Combine ablation results into a technoeconomic analysis to determine the most applicable materials and mining locations.

Table 2: Comparison to similar technologies

Concept	Mass	Power	Collection Rate	Elements
Arc Mining [2]	1,040 kg	2.3 kW	0.2 kg/kWh 0.001 kg/m.s	Water, volatiles, metals, metalloids
Heated Core Drill (PVex) [3]	14,000 kg	23.7 kW	0.05 kg/kWh (O_2) 0.008 kg/kWh (H_2)	Oxygen, Hydrogen
Resistive Thermal (Auger Dryer) [3]	1,960 kg	21.6 kW	0.05 kg/kWh (O_2) 0.009 kg/kWh (H_2)	Oxygen, Hydrogen
Direct Solar [4]	26,200 kg	N/A	16.1 kg/m^2	Water
Molten Regolith Electroysis (MRE) [5]	100 kg O_2 per kg of reactor mass	21 kWh per kg of O_2	0.05 kg/kWh	Oxygen (Silicon, Aluminum at higher powers)

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