ARTEMIS Steelworks

Advancing **R**eactor **T**echnologies for **E**lectrolytic **M**anufacturing of **I**n-situ **S**teel

Massachusetts Institute of Technology

For the 2023 BIG Idea Challenge: Lunar Forge

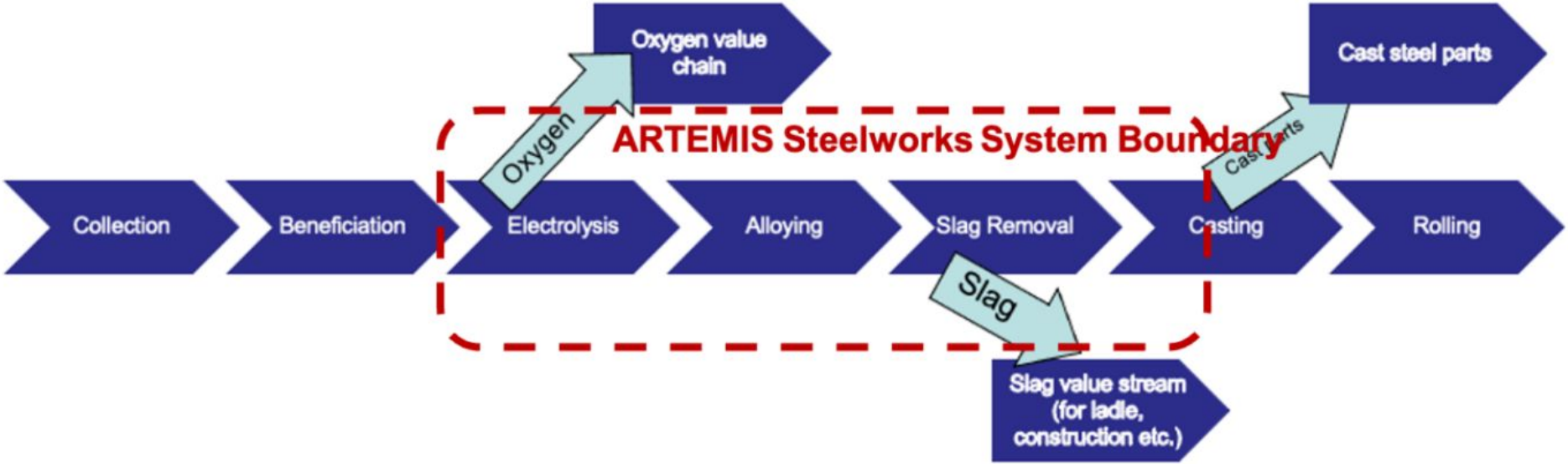
What is Artemis Steelworks?

ARTEMIS Steelworks will demonstrate the production of various alloys of lunar steel, with oxygen as a byproduct, from lunar regolith using the Molten Regolith Electrolysis (MRE) process.

Overview

- Technology - Molten Regolith Electrolysis reactor
- Innovation and Reliability on the Moon
- Lunar Metal Pipeline Value Addition

ARTEMIS Steelworks in the Lunar Metal Pipeline

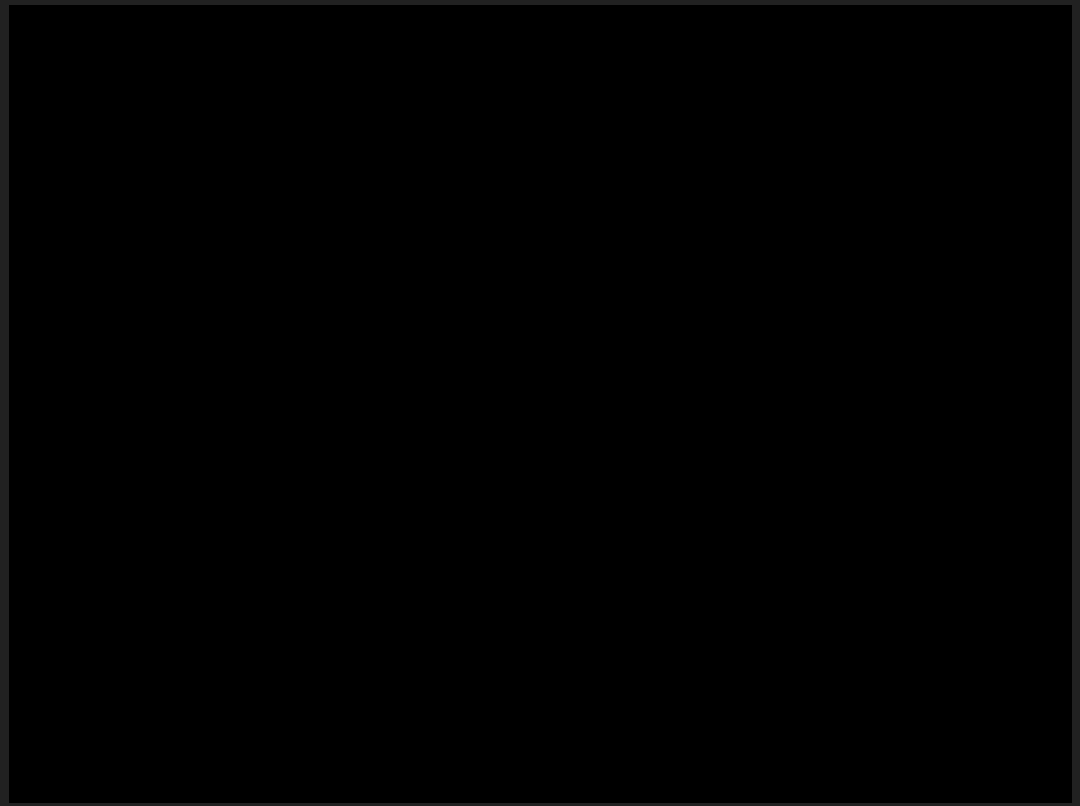


MRE

Molten Regolith Electrolysis

MRE Reactor in Operation

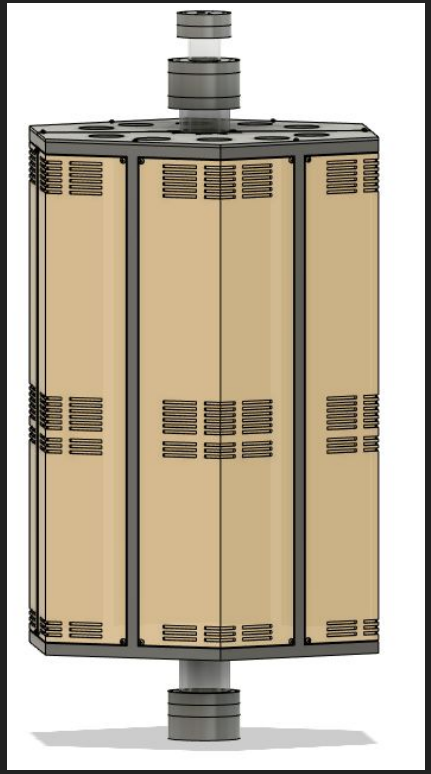
- Hopper
- Electrolysis
- Slow Extraction
- Full Extraction
- Automated Saw



Molten Regolith Electrolysis Overview

- Electrolytic separation of regolith into iron, oxygen and slag
- No additional inputs beyond regolith and energy
- Can be performed in a vacuum

- Approximately 1 kg of iron for 4 kg of regolith
- Regolith is **44%** oxygen by weight
- Capable of extracting up to **95%** of usable Oxygen [Schreiner et. al, 2015]

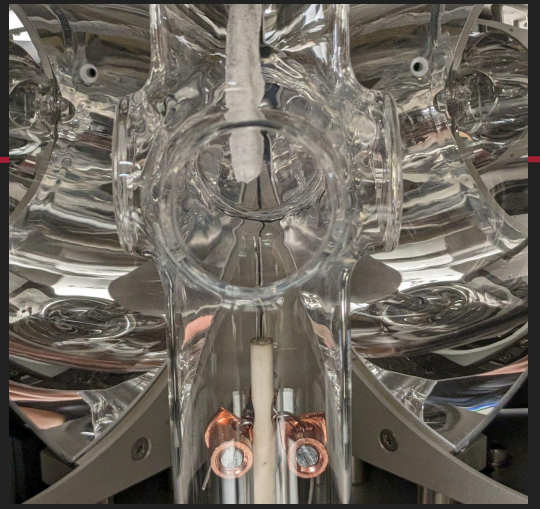


Early Render of our MRE Reactor

Innovation
&
Reliability on the Moon

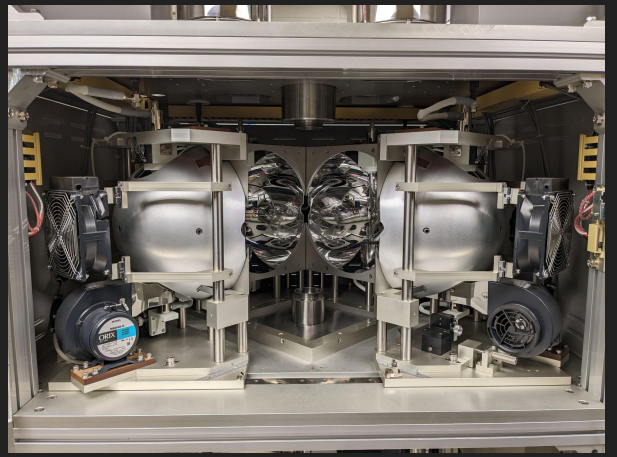
Reaction in a Vacuum Environment

Important to know whether we can produce metal the same way in a lunar vacuum environment.



Small scale test in a floating zone furnace under vacuum.

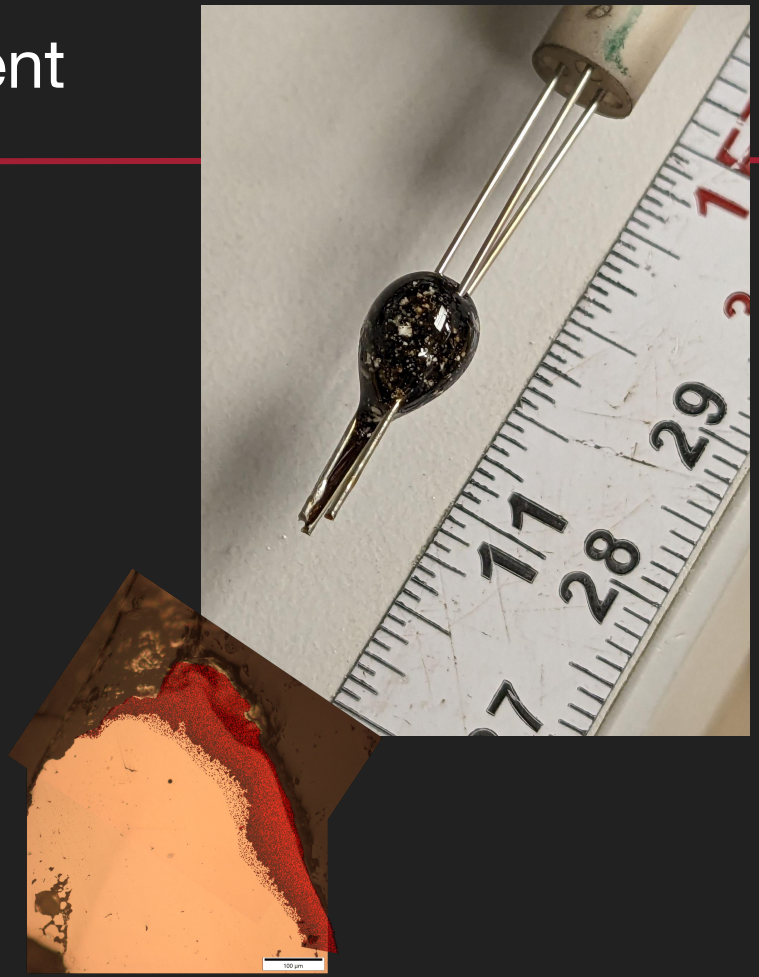
High intensity light used to heat the regolith and iridium electrodes used to perform electrolysis on a small scale.



Reaction in a Vacuum Environment

Results show iron alloy and slag cooled and collected on the iridium wire electrodes.

Preliminary results show **20-40 % wt** of iron in the produced alloy vs. **5-6 % wt** of iron in regolith. (Red highlights higher concentration of iron in the Energy Dispersive Spectroscopy image).



Release Bubbles from Electrodes to Improve Efficiency

Previous attempts at MRE and our small scale testing shows **gas buildup** as bubbles on the anodes.

Bubbles less likely to be released in lower gravity on the moon.

Gas bubbles present an issue in MRE efficiency.

The solution? The Sonicator.

Early sonicator tests show the ability to dislodge suspended gas.

Automation to Reduce Astronaut Time Requirement

ARTEMIS Steelworks will be **completely autonomous**

Astronaut man-hours will be a precious commodity on the moon.

All routine activities will be performed entirely autonomously on the moon:

Regolith feeding, MRE operation, iron rod extraction, iron slicing and slag separation

[FOR NOTE]

Can be performed with **non-beneficiated** regolith

No handling of molten metal

→ Reliability, safety

Nonconsumable iridium anode.

Equipment longevity, in case of failure reactor is far more recoverable.

Slag and Iron Slicer to Demonstrate Autonomy

End product from the reactor is solidified iron alloy and slag.

- Ensures safety + reliability
- Prevents equipment damage

The Slag and Iron Slicer can slice to remove slag, and slice to harvest new iron.

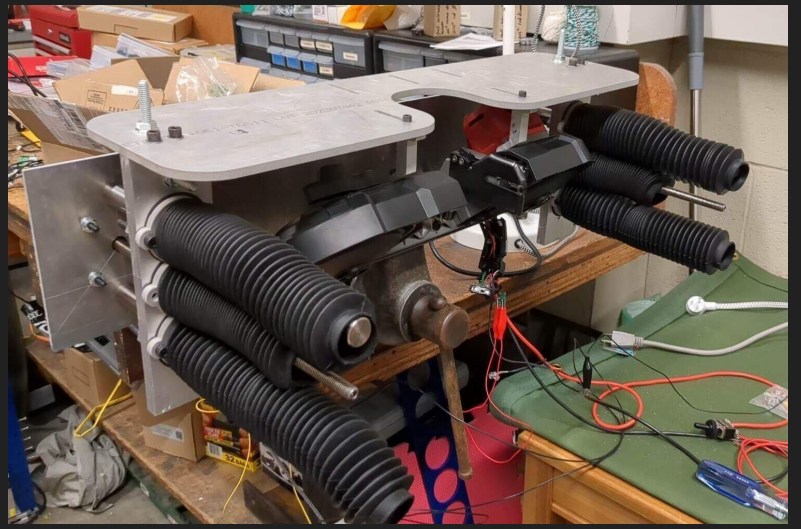
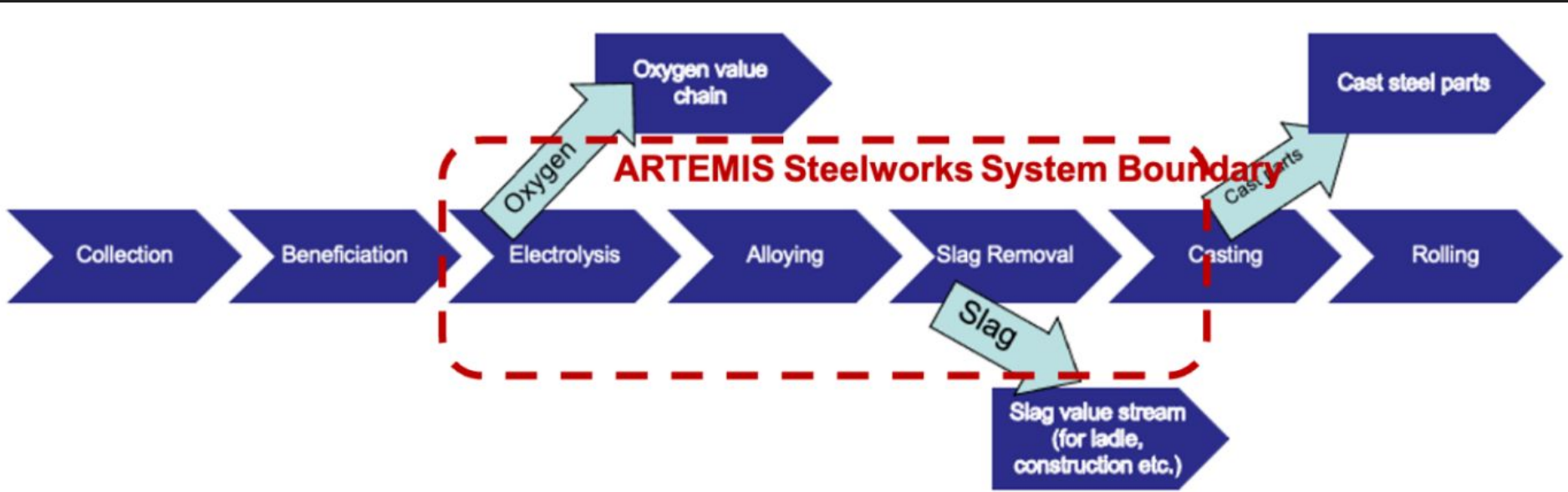


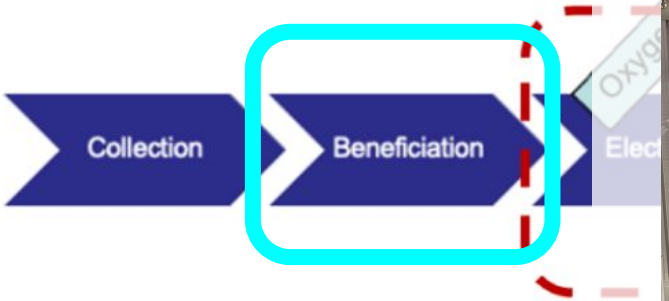
Image of our “Slag and Iron Slicer”
A key step in our Automation Process

Lunar Metal Pipeline Value Addition

ARTEMIS SteelWorks in the Metal Production Pipeline

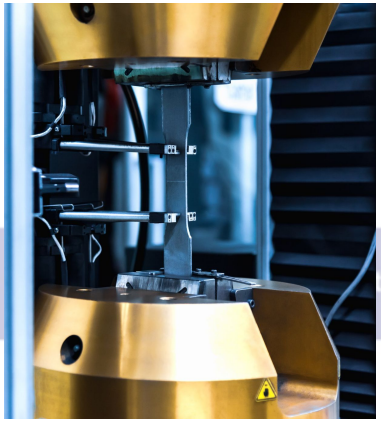


Beneficiation of Regolith not Required to Produce Metal



Original and beneficiated regolith in the small scale test produced an iron alloy.

Can the Metal Produced Manufacture Pressure Vessels?



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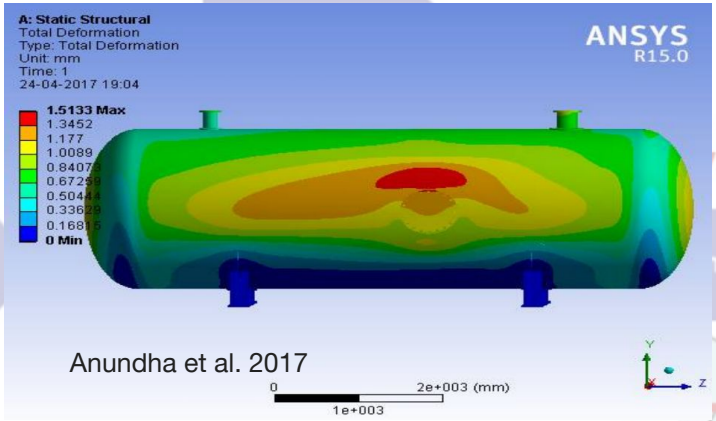
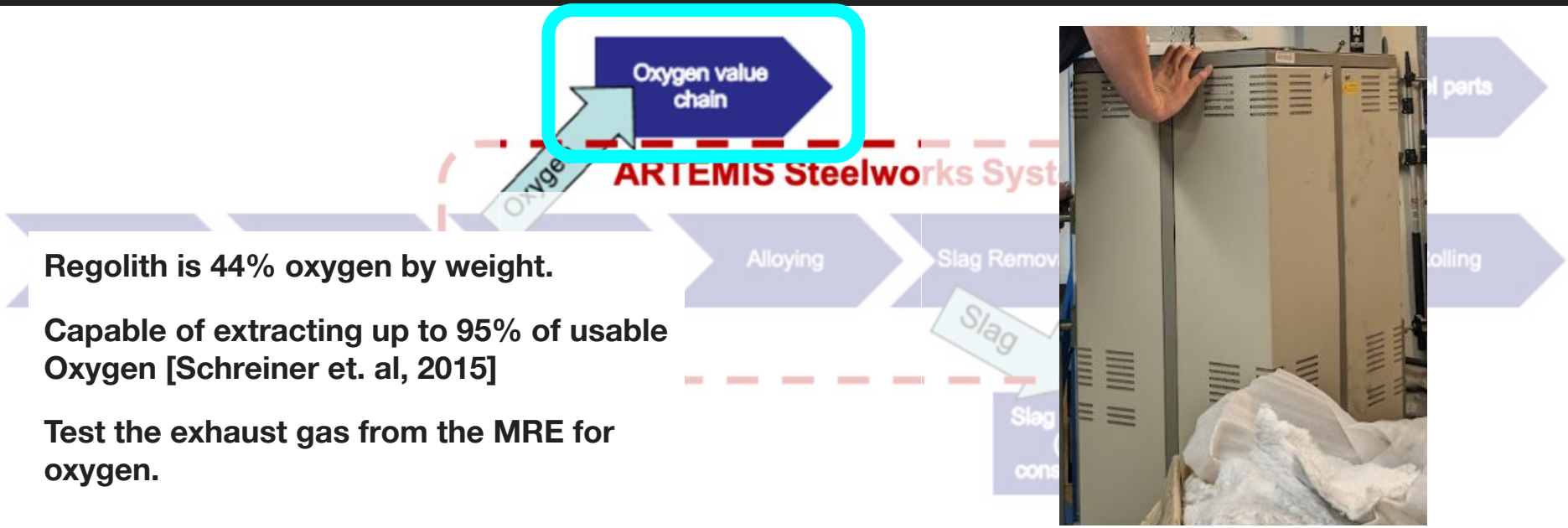


Anundha et al. 2017

Characterization and testing will provide material property data to simulate pressure vessel design and manufacturing for the moon.

Oxygen Produced as a Useful Byproduct

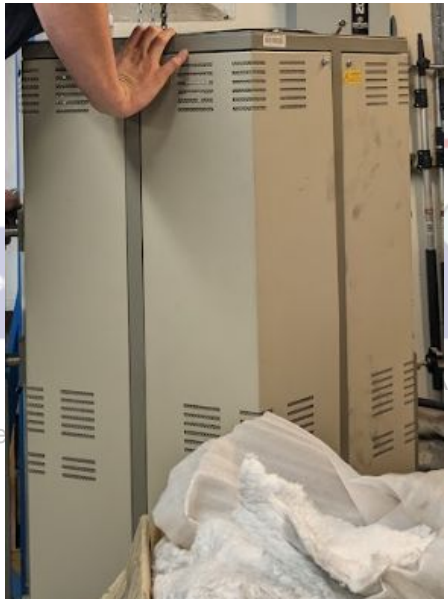


Regolith is 44% oxygen by weight.

Capable of extracting up to 95% of usable Oxygen [Schreiner et. al, 2015]

Test the exhaust gas from the MRE for oxygen.

Slag Produced as a Useful Byproduct

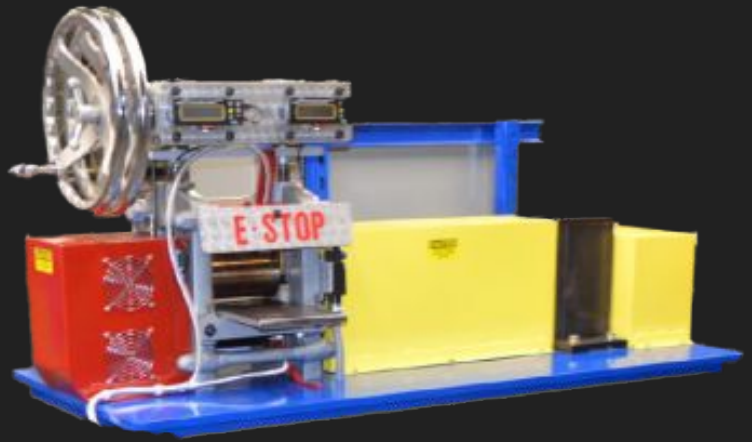


Slag collected from the MRE reactor can be used as refractory material on the Moon.

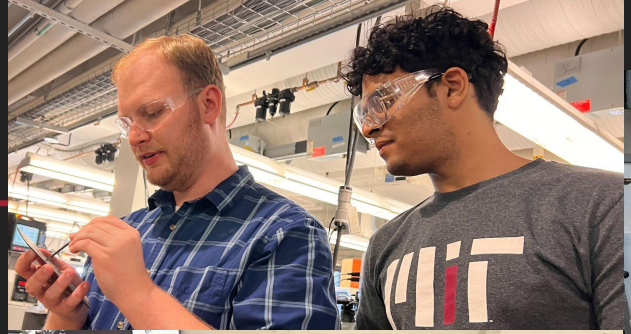
Products from our reaction will be used in a **cold rolling** setup at MIT.

We foresee this being the final manufacturing method in the metal production pipeline.

Produces thin metal sheets ideal for **pressure vessels**



Cold Rolling Setup at MIT's Taşan Group




Menu 24
Southwest Beef
and Black Beans
MRE

EXIT

DISPATCH
SPACEX

NASA

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