REGOLITH SIMULANTS

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DEVELOPING TECH FOR SPACE RESOURCES

Harvesting space resources requires unique hardware & processes that must be tested before going to the Moon or Mars or asteroids.

As we've seen in the course, the environments on other planetary bodies are unlike Earth. To some extent, these can be replicated using vacuum chambers, zero-G flights, etc.

But what about the materials?

Planetary materials share many similarities with terrestrial rocks, but there are many unique features as well.

For example:

- Lunar regolith is very fine grained with angular particles, agglutinates, nanophase iron, dangling bonds.
- Martian regolith very iron-rich, replete with amorphous phases, minor perchlorates, etc.
- Carbonaceous asteroids have incredibly fine-grained matrix (< 1 micron particles), carbon-rich.

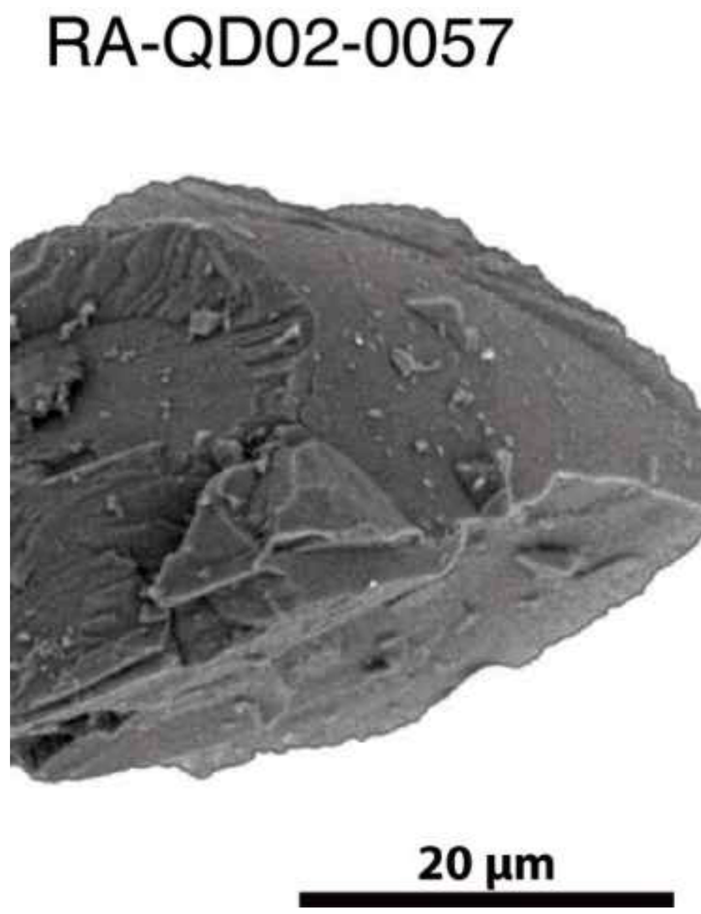
WHAT'S AVAILABLE TO USE?

One might ask why we don't just test on the real thing: Apollo astronauts brought back loads of samples from the Moon, and we have asteroid sample return missions.

BUT, the actual mass is very limited, these are the most precious and carefully curated materials that exist.

Material	Collection mass (kg)
CI chondrites	21.5
Apollo samples	382
Luna samples	0.3
Asteroid regolith	~1500 grains (micron-size)

Mining techniques are highly destructive, and vehicle testing requires huge amounts of material. Need another solution.



SIMULANTS

A **simulant** is a material that replicates one or more features of extraterrestrial materials.

More specifically, a **regolith simulant** aims to replicate the features of unconsolidated regolith.

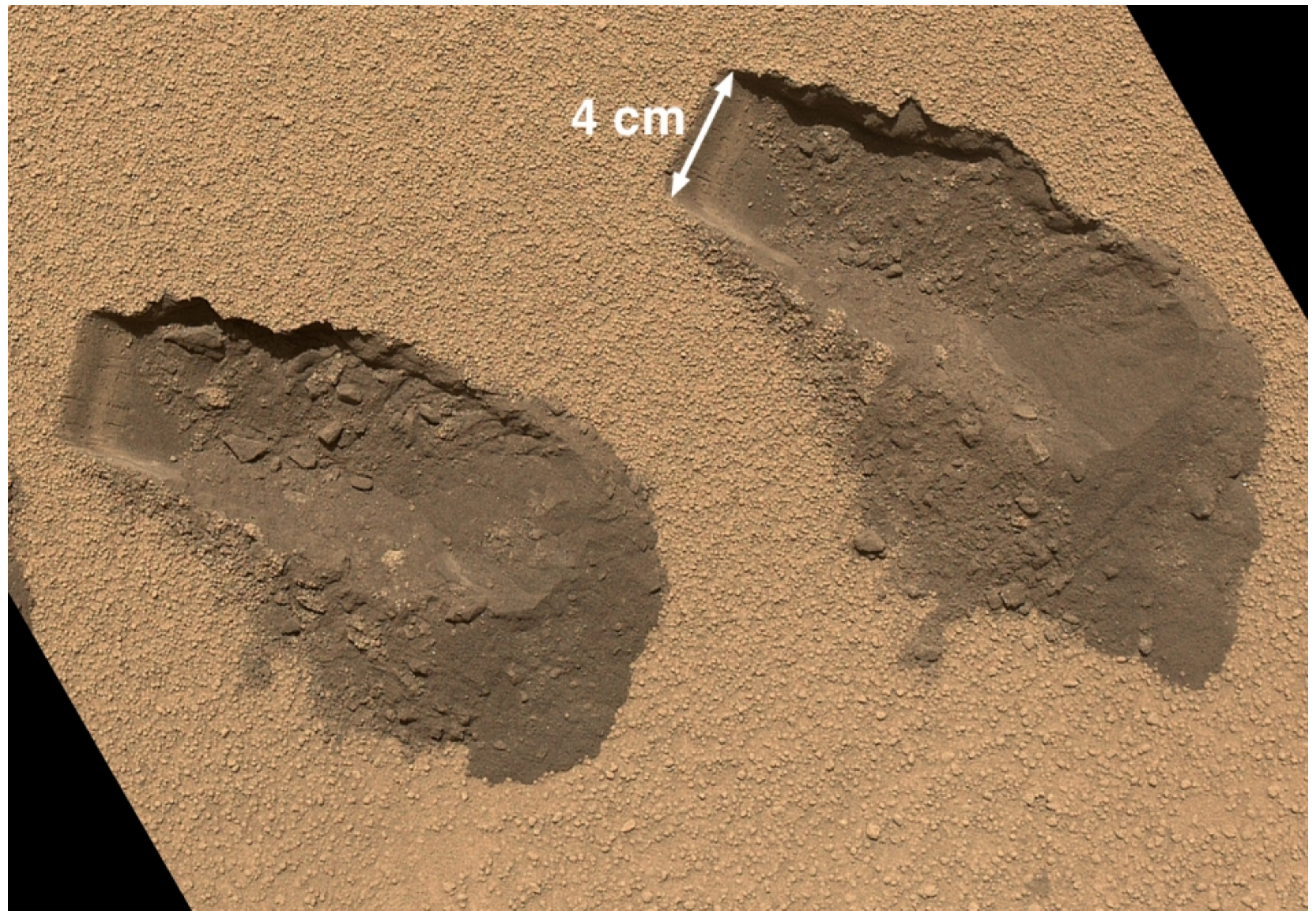
Simulants actually pre-date Apollo: different rocks were ground into powders in anticipation of what astronauts would encounter.

Some questions to ponder:

- Which properties of planetary materials should we aim to re-produce with simulants?

- How faithfully should the simulants mimic the real thing in order for results to be valid?

- How much time and money will it take to achieve that level of realism?



SIMULANT INFORMATION FLOW

Low-fidelity simulant based on incomplete info

enables

Orbital and landed missions to collect better data

enables

Better simulants created based on new data

Information flows this way

ISSUES WITH MANY HISTORIC SIMULANTS

Two main issues have plagued simulant efforts, most notably during the Constellation era:

1. Many simulants were low fidelity and simply consisted of a single terrestrial rock type ground into a powder. As an excuse, these were called "geotechnical simulants" even if they weren't altered to have accurate geotechnical properties.

2. Nobody came up with a good way to distribute simulants to those who needed them.

SOLUTION #1: MINERAL-BASED SIMULANTS

Minerals are the basic building blocks of planetary materials.

Most properties (physical, thermal, optical, etc.) are a function of the mineralogy much more so than chemistry.

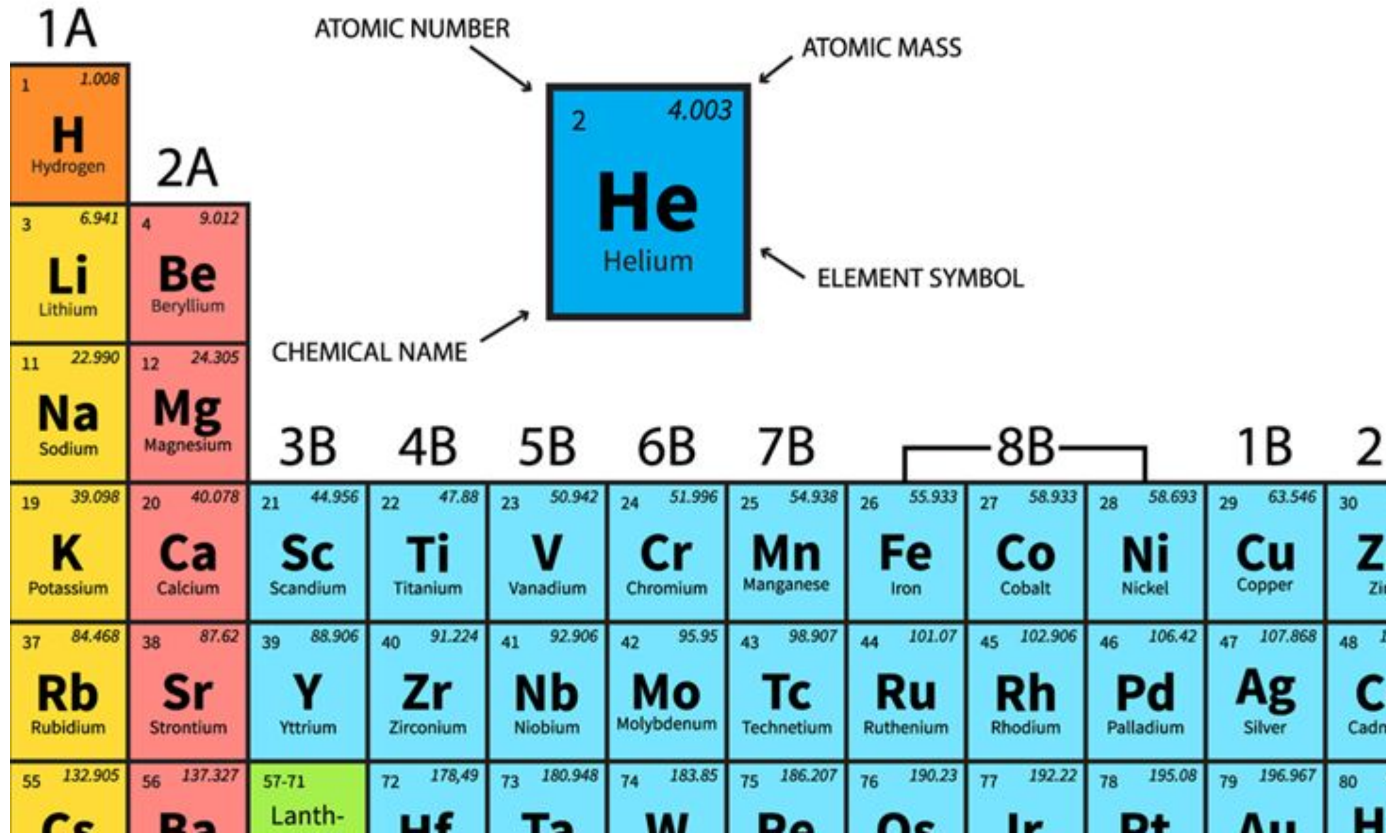
PSD-XRD of chondrites allows for accurate mineralogy of asteroid simulants, CHEMIN on Mars for martian simulants.

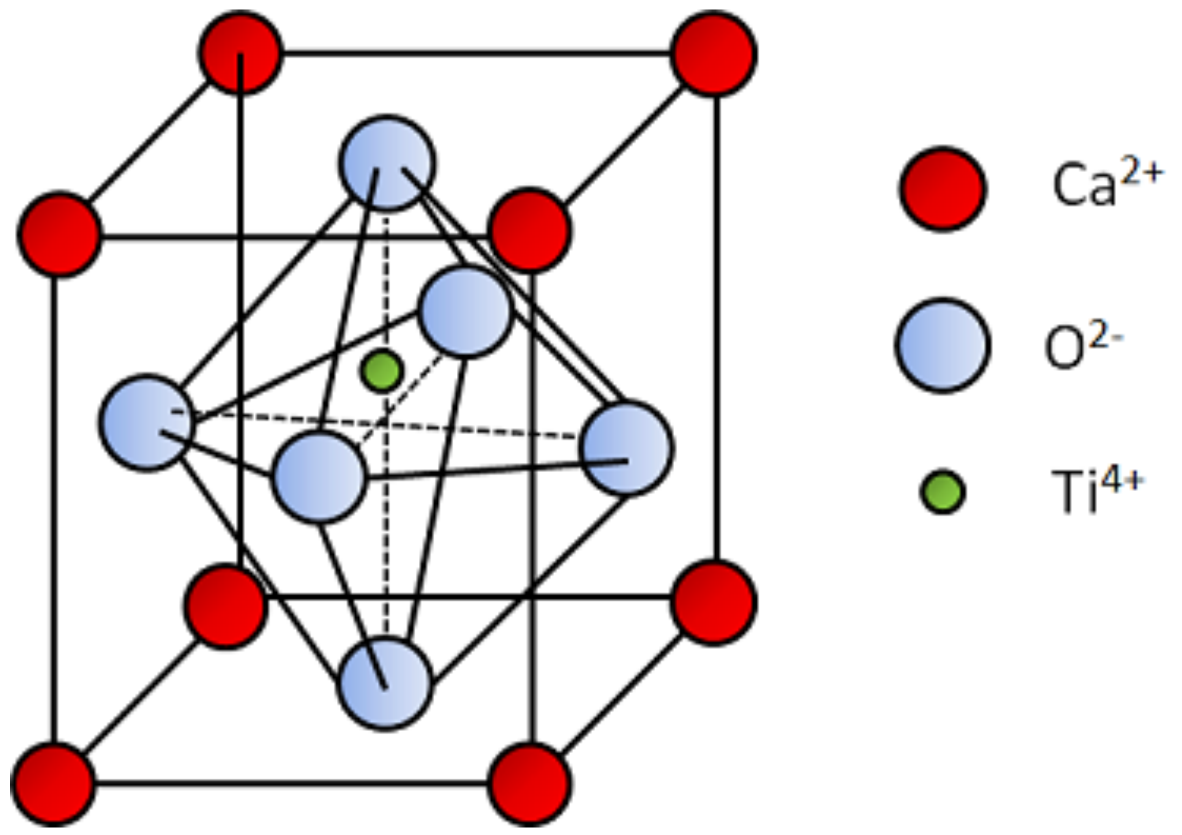
X-ray diffraction

Mineral	Wt.%
Mg-serpentine	51.3
Magnetite	10.0
Vermiculite	9.6
Olivine	7.0
Pyrite	7.0
Attapulgite	5.3
Sub-bituminous coal	5.0
Ferrihydrite	4.8

MINERALOGY VS. CHEMISTRY

Elements → Minerals → Rocks





Fe Si Mg O

SOLUTION #2: A BETTER DISTRIBUTION SYSTEM

Profit margins on simulants are negligible. Many companies have tried to sell them for-profit and have failed.

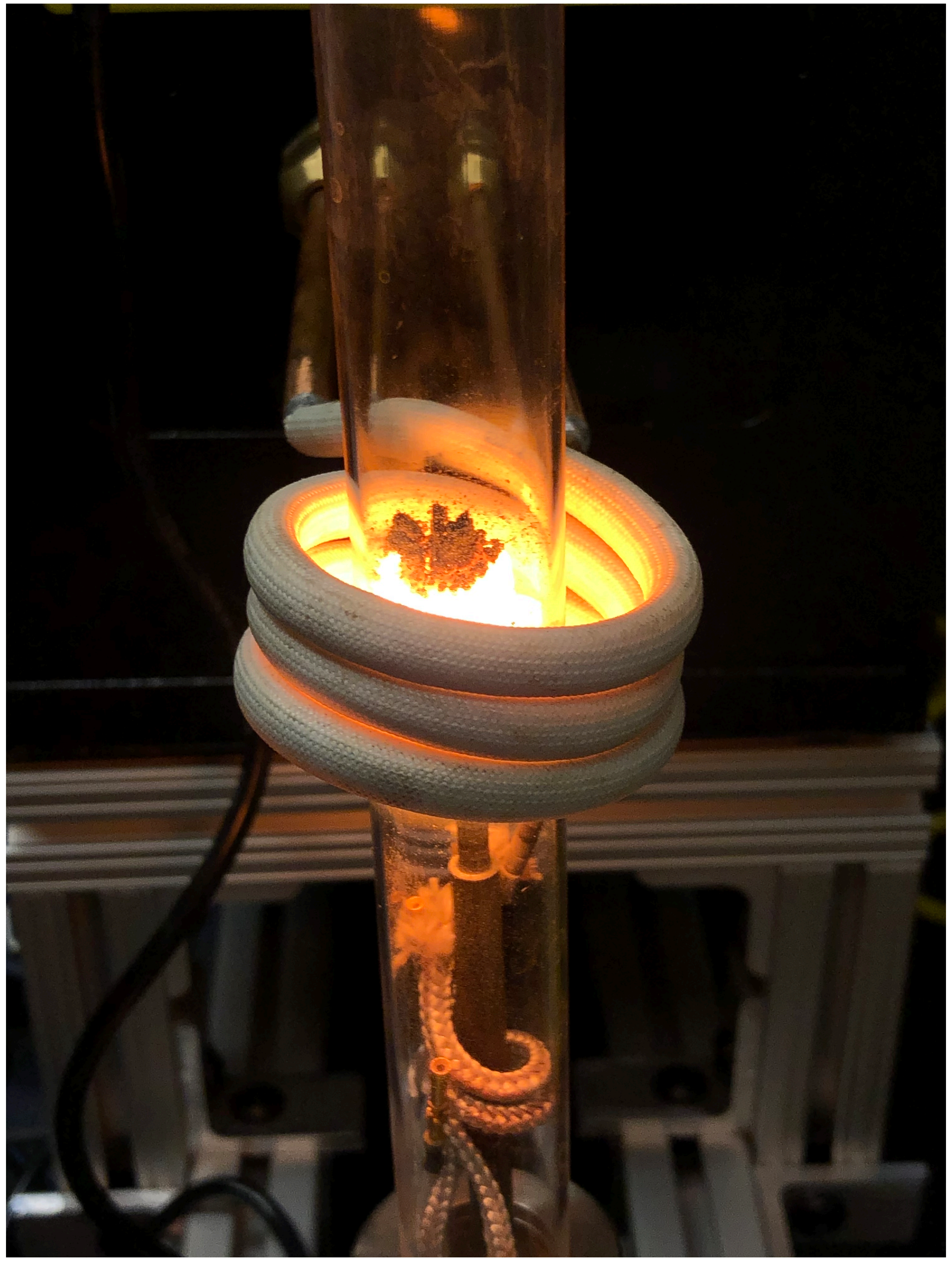
CLASS Exolith Lab: not-for-profit entity, set up under UCF Research Foundation.

Full suite of asteroid, lunar, and martian regolith simulants.

Manufactures & distributes simulants worldwide to researchers, space agencies, private companies, STEM education.

SIMULANT APPLICATIONS: HOME-GROWN EXAMPLES

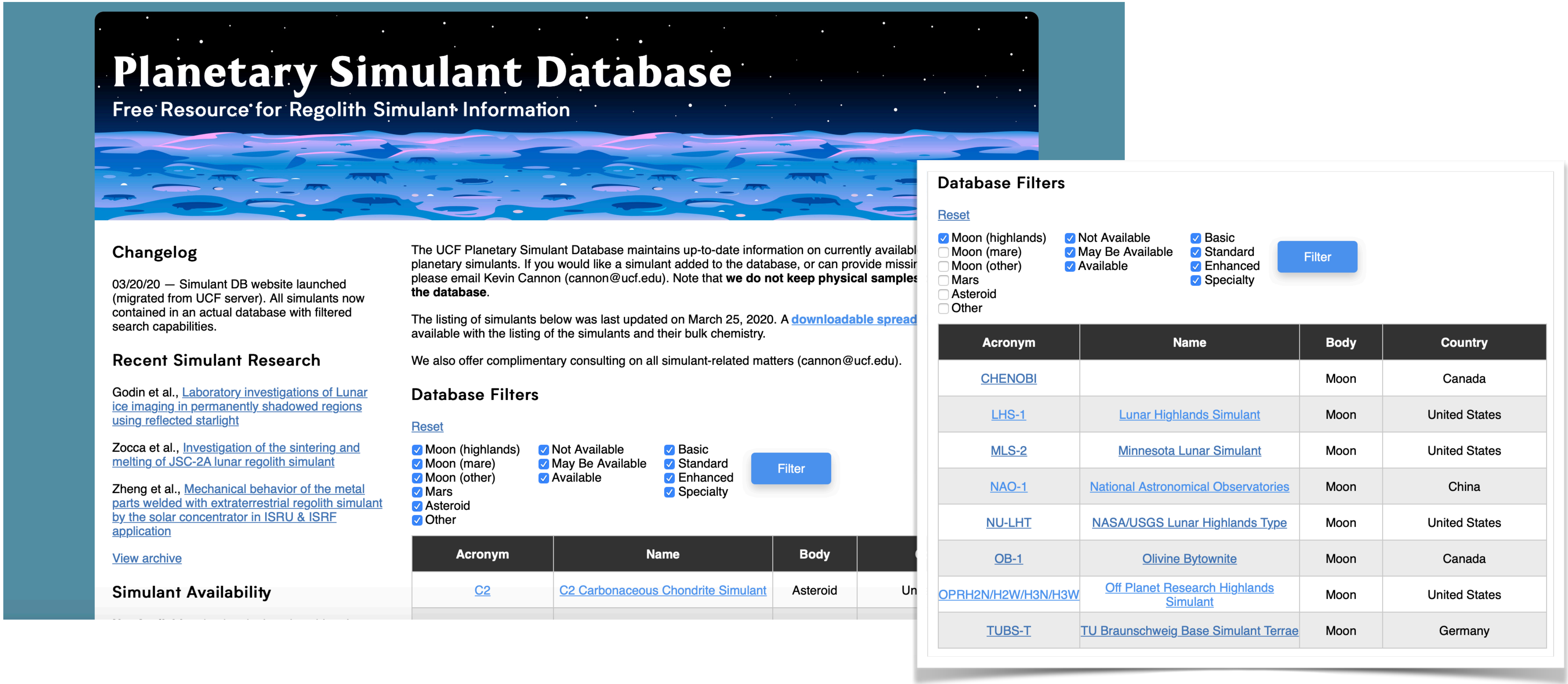
Simulated C-type asteroid for TransAstra's Mini Bee orbital flight demo mission



Lunar mare simulant being tested with HELIOS's molten regolith electrolysis methods to extract oxygen from lunar regolith

PLANETARY SIMULANT DATABASE

https://simulantdb.com



FINAL THOUGHTS

At the end of the day, simulants are just crushed up rock.

It’s probably not worth putting a significant amount of time, brainpower, and money into simulants (80:20 rule), or studying the simulants in and of themselves.

The goal of using simulants should be to create a future where they aren’t needed anymore.