BIOMINING FOR IN SITU RESOURCE UTILIZATION OF LUNAR MINERALS K. Bywaters[1], E. Seto[1], N. Bouey[1] and K. Zacny[1], 1Honeybee Robotics, 2408 Lincoln Ave, Altadena, C 91001. (Contact: kfbywaters@honeybeerobotics.com)

Introduction: Moon offers minerals resources including silicon and aluminum (Table. 1). Biomining, the process of using microorganisms to extract metals of economic interest from rocks and regolith, offers an attractive method for making in situ resource utilization (ISRU) of Lunar minerals possible. As a part of microbial metabolism, microorganisms produce organic acids, and these can be used to leach metals in the biomining process. Biomining is currently being used, on Earth, in the mining industry to extract Cu, Al, Fe, and Au and obviate the requirement for toxic chemicals.

Table 1. Composition of a lunar mare sample 10017 [1].

Element	Lunar Sample 10017, weight %
Oxygen	40.7
Silicon	19.6
Aluminum	4.4
Iron	14.6
Calcium	8.2
Magnesium	4.8
Sodium	0.347
Potassium	0.206
Titanium	7
Manganese	0.148

European Space Agency (ESA)'s European Programme for LIfe and Physical Sciences in Space (ELIPS) project BioRock, investigated the behavior of microbes in contact with particles in altered gravity regimens on the International Space Station (ISS) to evaluate if microbial-supported bioproduction and life support systems can be effectively performed in space. In BioRock, microorganisms were dried on rock samples and then rehydrated once on the ISS. The microorganisms were then allowed to grow and extract elements from the rocks. BioRock found no significant differences in the microorganism growth between different gravity regimes [2].

Considering the BioRock experimental results and the mineral resources available on the Lunar surface, we propose using biomining as a method for Lunar ISRU.

Lunar Regolith Simulant Experiments: To investigate the bioleaching efficiencies of different strains and evaluate the production potential of aluminum extracted from Lunar regolith simulants, using microorganisms, the following experimentation is conducted.

Aspergillus foetidus, species of fungus, and *Acidithiobacillus ferrooxidans*, an acidophilic and chemolithoautotrophic bacterium, were selected. Both organisms are known for effective metal solubilization. Cultures will be grown in media containing Lunar Highland Simulant (LHS-1). Over the culturing duration, glucose consumption and organic acids (citric acid in *Aspergillus foetidus* cultures and sulfuric acid in *Acidithiobacillus ferrooxidans* cultures) production will be quantified using high performance liquid chromatography (HPLC) to investigate the corresponding bioleaching efficiencies. Inductively coupled plasma mass spectrometry (ICP-MS) will be used for Al analysis of culturing media over the duration of the experiments to determine production rates. Scanning electron microscope (SEM) images will also be taken to evaluate any changes in the morphology of the simulant.

Lunar Operational Scenario: Biomining the Lunar surface would be a straightforward process, very similar to the procedures used on Earth. Regolith would be mixed with microorganisms and nutrients, then allowed incubated for 1-5 days (depending on the organism and culturing conditions) to provide time for the microorganisms to extract metals into solution. During this period, culturing conditions, such as pH, temperature, mixing, would need to be maintained. Metals would then be extracted from the solution using conventional methods (e.g., electrowinning or precipitate).

Conclusion: From these experiments we will quantify the production rates of Al from Lunar simulate using microorganisms. These data will feed into an analysis of the feasibility of employing biomining as a strategy for ISRU of Lunar materials.

References: [1] Wänke, H., et al. (1970) *Lunar and Planetary Science Conference Proceedings.* Vol. 1. [2] Santomartino, R., et al. (2020) *Frontiers in Microbiology* 11: 579156.