**ASTRONAUT-DRILLING SIMULATION FOR SIGNS OF LIFE.** E. P. Seto[1], K. Zacny[1], M. Musilova[2,3,4], [1]Honeybee Robotics (epseto@honeybeerobotics.com), [2]International Moonbase Alliance, United States (musilova@moonbasealliance.com), [3]Institute of Robotics and Cybernetics, Faculty of Electrical Engineering and Information Technology STU in Bratislava, Slovakia, [4]Slovak Organisation for Space Activities (SOSA), Bratislava, Slovakia

**Introduction:** Lava tubes can be found on Earth and similar structures have been identified on Mars and the Moon. In lava tubes, microbial processes aid in the formation of minerals present from surrounding basaltic rock [1]. Understanding the distribution of microbial life in analog extreme environments can provide critical clues for biosignatures and signs of past or present life that may exist on Mars and Moon. To search for molecular biomarkers will require sample acquisition below the desiccated and irradiated surfaces. We simulated an astronaut-drilling mission for signs of life in the lunar subsurface using Honeybee Robotics' surface coring drill that has been designed to acquire rock and boulder samples. Core samples and subsurface samples were successfully taken in various locations in the lava tubes to observe microbial diversity.

**Research:** The Hawaii Space Exploration Analog and Simulation (HI-SEAS), is a habitat that is located at the north-eastern flank of shield volcano Mauna Loa, Hawaii [2]. Operations of simulated missions coordinated by the International Moonbase Alliance (IMA), provided opportunities to study the surrounding habitat which bears similarities with surface conditions on the Moon and Mars (Figure 1). The subsurface of the Moon and Mars may include lava tube structures, which are abundant and may provide protection for life from solar radiation. Therefore, the subsurface could be habitable for extraterrestrial life.

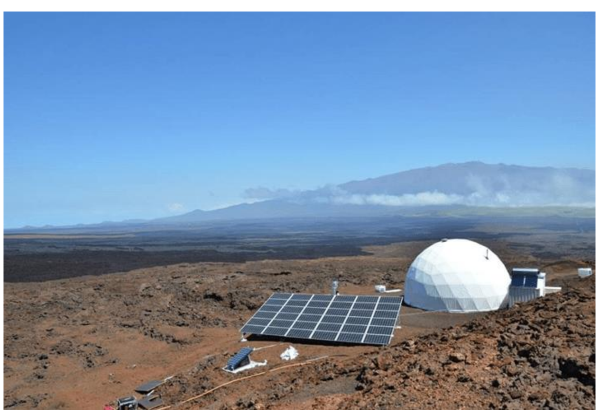

**Figure 1: The HI-SEAS habitat is surrounded by basaltic lava flows that shows resemblance to lunar and Martian basalts.**

Honeybee Robotics has been developing numerous geo-related tools for robotic exploration and some have been modified and deployed in various planetary analog field sites. The coring bit is using Honeybee-patented core break off technology that has been selected by NASA JPL for its Mars2020 coring drill (first step in the Mars Sample Return Campaign) [3]. The drill has been designed specifically for capturing rock cores from large boulders or rocks, or from rocks too large to be transported back to Earth. The system has been adapted to be used by scientists on Earth and astronauts on the Moon or Mars (Figure 2). In particular, it uses COTS (e.g. HomeDepot Hilti) hammer drill with custom made coring bits and borehole starters. It allows for easy coring and either bagging of the core for in-lab analysis or for in-situ analysis without removing the core from the breakoff coring system. The suitcase size toolkit was developed during the NASA Astrobiology Institute project (PI. Cabrol).

During a two-week lunar simulation, the Honeybee coring drill was used at HI-SEAS surrounding lava tube habitats for sample collection. Field research was conducted in lunar analog astronaut suits, creating new observations for aseptic sample collection and drill assembly.

**Figure 2: Astronaut-drilling simulation using Honeybee Robotics' coring drill. Lunar analog astronaut suits were worn during field work to simulate "extravehicular activity".**


**Figure 3: Honeybee Robotics' coring drill used for sample collection.**

Detailed planning eliminated some of the challenges and minimized contamination concerns. For example, the drill bits were mechanically cleaned with IPA and wrapped in foil before deployment in the field. Drilled samples were collected in sterile cups with glove changes in-between sample collection events to minimize contamination.

**Figure 4: Aseptic transfer of collected core sample to sterile container.**

We observed that mobility restrictions resulted from donning nitrile gloves over the astronaut gloves during sample collection events. However, this could be easily mitigated by utilizing larger nitrile glove sizes. Once samples were collected, they were prepared in the Habitat laboratory for downstream analysis (sequencing). Physical manipulation and splitting of the samples were performed with wearing nitrile gloves and IPA cleaned spatulas.

The samples were strategically taken at different locations in the lava tube to compare the microbial population. Each location in the lava tube is exposed to different environmental conditions. Closer to the entrance, oxygen and sunlight provide additional source of nutrients for microbial growth while the end of the lava tubes have less light and oxygen. Future work will include continued sample collection and analysis to understand the microbial life in analog extreme environments. This was the first time an astronaut drill had been deployed to collect core samples in lava tubes surrounding the HI-SEAS habitat. Additionally, we were able to make observations and protocols for sample collection in lunar analog astronaut suits.

**Acknowledgments:** I would like to thank the Sensoria M3 crewmembers for supporting me during the analog Moon mission: Michaela Musilova, Niko Blanks, Lea Miller, Gianna Torres, and James Ward (for the photographs). Also, I would like to acknowledge IMA, Henk Rogers, and Blue Planet Research for making the operation and research possible. For the drill-related operations, I would like to thank Justin Springs, Amelia Grossman, Jackson Yeung, and Kris Zacny for their guidance.

**References:** [1] C.D., Richardson, N.W., Hinman, and J.R. Scott (2013) Evidence for biological activity in mineralization of secondary sulphate deposits in basaltic environment: implications for the search of life in Martian subsurface. International Journal of Astrobiology, 12 (4) 357-368, [2] M. Musilova. et al., Geophysical Research Abstracts (2019), vol. 21, p1-1.1p [3] Zacny et al., LPSC 2020.