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## Simulating lava tube exploration research during analog lunar and Martian missions at HI-SEAS in Hawaii

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Lava tube exploration has become an important part of discussions relating to the search for life on Mars by both humans and robots. On Mars, lava tubes may contain biosignatures and existing lifeforms. Alternatively, on the Moon, lava tubes may serve as sheltered environments for the construction of human settlements. Nevertheless, lava tubes can also be difficult environments for robotic operations and they can pose a safety hazard to humans as well. It will thus be extremely important to prepare for lava tube exploration by humans and robots in analog environments on Earth. The Hawaii Space Exploration Analog and Simulation (HI-SEAS) habitat is a lunar and Martian analog research station located on the volcano Mauna Loa in Hawaii. The International MoonBase Alliance (IMA) organises missions at HI-SEAS, during which crews of six analog astronauts perform research and technology testing relevant to the exploration of the Moon and Mars. The missions that take place at HI-SEAS can be of varied duration, from several days to several months, depending on the needs of the researchers. They are open to space agencies, organizations and companies worldwide to take part in, provided their research and technology testing will help contribute to the exploration of the Moon and Mars. Since the HI-SEAS habitat is located on lava flows, its surroundings provide valuable access to performing high-fidelity planetary science fieldwork with very little plant or animal life present, and a wide variety of volcanic features to explore, such as lava tubes, channels, and tumuli. This terrain is also ideal for rover and in situ resource utilization (ISRU) testing because of its great similarity to the basaltic terrains on the Moon and Mars. HI-SEAS crews have performed a number of biochemical and geophysical research projects in the lava tubes accessible to them near the habitat. They explored and collected research samples while wearing Extra-vehicular Activity (EVA) analog spacesuits and following strict EVA protocols. These activities are very challenging for the crew, due to the bulky gloves and EVA equipment they have to wear, while performing precise biochemical research that is sensitive to contamination. The crews also have to take into consideration their safety, their limited life support systems during EVAs and a number of other factors relevant to space exploration missions. Further studies will be needed to assess how best to combine scientific goals with human exploration goals during future human missions, which may use lava tubes as a

resource as well as a key site for scientific research.