EUROMOONMARS IMA AT HI-SEAS CAMPAIGNS IN 2019: AN OVERVIEW OF THE ANALOG MISSIONS, UPGRADES TO THE MISSION OPERATIONS AND PROTOCOLS.

M. Musilova[1,2,3,4,5], B.Foing[1,2,6,7], A. Beniest[1,2,7] & H. Rogers[1,2,3]
[1]ILEWG EuroMoonMars programme, [2]EMMIHS (EuroMoonMars - International Moonbase Alliance - HI-SEAS), [3]International Moonbase Alliance (IMA) & Hawai´i Space Exploration Analog and Simulation (HI-SEAS), United States (musilova@moonbasealliance.com), [4]Institute of Robotics and Cybernetics, Faculty of Electrical Engineering and Information Technology STU in Bratislava, Slovakia, [5]Slovak Organisation for Space Activities (SOSA), Bratislava, Slovakia, [6]ESA ESTEC, Noordwijk (bernard.foing@essa.int) & ILEWG. [7]Vrije Universiteit Amsterdam (a.beniest@gmail.com)

Introduction: The Hawaii - Space Exploration Analog and Simulation (HI-SEAS) habitat is located at 8,200' (2,500 meters) in elevation on the active volcano Mauna Loa, on the Big Island of Hawai'I [1]. As of 2018, the International Moonbase Alliance (IMA), an organization dedicated to building sustainable settlements on the Moon, has been organizing regular simulated missions to the Moon and Mars at HI-SEAS. The constraints for these missions depend on which celestial body the mission is simulating to be on. For instance, for lunar missions the time delay in communications is only of a few seconds, in comparison to the 20 minute one way delay imposed on communications with Mars. In 2019, the EuroMoonMars campaign was launched at HI-SEAS, bringing together researchers from the European Space Agency (ESA), IMA, the International Lunar Exploration Working Group (ILEWG), European Space Research and Technology Centre (ESTEC), VU Amsterdam and many other international organizations [2,3]. During this campaign, two crews spent two weeks each at HI-SEAS in 2019, performing research relevant to both the Moon and Mars there [4,5]. The campaign aims to increase the awareness about the research and technology testing that can be performed in analogue environments, in order to help humans become multiplanetary species. Furthermore, the research and technological experiments conducted at HI-SEAS are going to be used to help build a Moon base in Hawai'i, and ultimately to create an actual Moon base on the Moon, as part of IMA's major goals [6].

EuroMoonMars IMA HI-SEAS campaigns: HI-SEAS has been the home to five successful long duration (4 to 12 month) NASA Mars simulation missions since 2013 [1]. A HI-SEAS Mars mission involved six person crews being isolated from the rest of humanity for long periods of time. While in the simulation, communications with "Earth" were delayed by up to 20 minutes each way. When the crew left the HI-SEAS habitat, they wore analog space-suits and they went through full extra vehicular activity (EVA) protocols to perform their research in the simulated Martian terrain.

Fig 1. EMMIHS crewmembers performing geology research during an EVA.

IMA has been organizing simulated missions to the Moon at HI-SEAS since 2018. These missions can be of shorter duration, from several days to several weeks, depending on the needs of the researchers. They are open to space agencies, organizations and companies worldwide to take part in, provided their research will help contribute to the exploration of the Moon and Mars. The research can involve scientific experiments, human based studies and technology testing. The crews will be supported by a Mission Control Center (MCC) based on the Big Island of Hawai'i as well.

As of 2019, a series of EuroMoonMars IMA HI-SEAS (EMMIHS) missions have been taking place at HI-SEAS. These missions are under the EuroMoonMars initiative, led by ILEWG of ESA in collaboration with IMA. These missions involve performing geological, biological and architectural research; technological tests using drones and rovers; as well as performing outreach and educational projects.

Results of the EMMIHS I & II Campaigns: Both EMMIHS campaigns in 2019 consisted of a two-week simulated mission on the Moon with a six person crew. The crew was isolated within the HI-SEAS habitat, which they could not leave without performing EVAs in analog space-suits and with the permission of

MCC [2,3,4,5]. The MCC was based at the Blue Planet Research laboratory, which is about an hour and a half away from the HI-SEAS habitat. Further support from the crew was provided by the remote support team based at the EuroMoonMars center at ESA/ESTEC in Noordwijk, the Netherlands.

EMMIHS I took place from February 20th to March 6th 2019 and EMMIHS II took place from December 8th to the 22nd 2019. During both missions, the crew performed extensive research projects and exploration EVAs. Their projects involved collecting geological and geochemical samples with implications for astrobiology, past lunar and Martian geology, and for habitability research purposes. The crews also performed architectural research inside the habitat and inside lava tubes, with implications on human psychology during long duration space missions. Furthermore, the crew also studied the effects of radiation on humans and the potential of growing food using local regolith.

From a technological point of view, the crews also tested various equipment that is likely to be of great importance to humans living on the Moon and Mars. These included different types of rovers, drones and 3D printers. All of these technologies turned out to be very useful and needed by the crews. Future campaigns will be further developing tests on these devices and they will be integrating them even more into the mission operations.

Finally, the crews also focused on performing outreach and educational activities during both missions. Their goal was to reach out to and inspire as many young people as possible to be interested in STEM subjects. Some of these projects involved installing a Moon gallery at the HI-SEAS habitat, creating videos for school children during the missions and performing research experiments designed by students all around the world. One of these experiments, for example, was designed by high school students in Slovakia as part of a nationwide competition organized by the HI-SEAS Director Dr. Michaela Musilova. It focused on fertilizing soils using human hair from the crewmembers.

Future plans: Future missions at HI-SEAS include more EuroMoonMars IMA HI-SEAS missions (EMMIHS III and IV are taking place in January and February 2020), collaborative missions with ESA, NASA, University of Hawai'I, University of South Florida and with companies, such as SIFT and Ketone Technologies. SIFT's Ad Astra software analyzes textual data to gain insights into crew members' dynamics and identify psychological stressors [7]. Ketone Technologies is studying the effects of nutritional ketosis in extreme environments and the possibility of sustaining ketosis using ketone supplements [8].

The end goal of these missions is to establish a playbook for living on the Moon, Mars and beyond. This playbook will include the development and testing of closed-loop systems, in situ resource utilisation and other sustainable processes. Part of the closed loop technology testing will be the design and construction of greenhouses and agricultural systems at HI-SEAS by crews participating in missions. These activities will be performed in parallel to in situ resource utilisation technology testing, for instance, the development of bricks made of analog lunar materials, which could then be used to build additional buildings in a Moon base.

Acknowledgments: First, we would like to thank the EMMIHS I & II crews (M. Musilova, S. Mulder, A. Weert, N. Sirikan, J. Burstein, B. Pothier & M.Musilova, S. Kerber, A. Wanske, J. D'Angelo, A. P. Castro de Paula Nunes, C.R. Pouwels) for their hard work during the simulated missions to the Moon. We would also like to thank the Mission Control from HI-SEAS (A. Cox, P. Ponthieux et al.) for their support from 'Earth' and we acknowledge the ILEWG EuroMoonMars manager B. Foing for making this research possible during the EMMIHS campaigns, and the remote support team (J. Ageli, J. Preusterink, A. Beniest, A. Sitnikova et al.).

References:

[1] Hawaii Space Exploration Analog and Simulation, https://hi-seas.org

[2] Musilova M, Rogers H, Foing B , Sirikan N. et al (2019), EMM IMA HI-SEAS campaign February 2019, EPSC-DPS2019-1152

[3] Foing, B. H.; EuroMoonMars 2018-2019 Team, EuroMoonMars Instruments, Research, Field Campaigns, and Activities 2017-2019; 2019LPI....50.3090

[4] Sirikan, N., Foing, B., Musilova, M., Weert, A., Pothier, B., Burstein, J., ... & Rogers, H. (2019). EuroMoonMars IMA HI-SEAS 2019 Campaign: An Engineering Perspective on a Moon Base, the International Astronautical Congress, 21-25 October 2019. Washington DC, United States.

[5] Musilova, Michaela, Henk Rogers, and Bernard Foing. "Analogue research performed at the HI-SEAS research station in Hawaii." Geophysical Research Abstracts. Vol. 21. 2019.

[6] International MoonBase Alliance, https://moonbasealliance.com/, (accessed 03.10.19).

[7] Ad Astra, 2019, https://www.sift.net/demos/ad-astra.

[8] University of South Florida, 9 June 2017, https://phys.org/news/2017-06-nasa-mission-ketogenic-diet-undersea.html, (accessed 03.10.19).