

Exploring the Benefits of Analog Astronautical Simulations in ICEE (Isolated, Confined Extreme Environments) as Preparation for Geological Artemis EVAs (Extra-Vehicular Activities)

C. Pouwels^{1,3,7}, E.C. Poli², M. Musilova^{4,5,6,7}, A.P.C.P. Nunes³, J. Toop-Rose⁷, M. V. Heemskerk^{1,3,7,8}, B. Foing³

¹CHILL-ICE (charlotte.pouwels@gmail.com) ²(eleonorepoli27@gmail.com, University of Cambridge, Philippa Fawcett Road, Cambridge, United Kingdom. ³ILEWG-EuroMoonMars, ESA/ESTEC, Keplerlaan 1, Noordwijk, The Netherlands; ⁴International Moonbase Alliance, United States (musilova@moonbasealliance.com), ⁵Institute of Robotics and Cybernetics, Bratislava, Slovakia; ⁶Slovak Organisation for Space Activities, Bratislava, Slovakia; ⁷(tooprose@outlook.com) International Space University, Strasbourg, France, ⁸Vrije Universiteit Amsterdam, The Netherlands (marc@chill-ice.com)

Introduction: The Moon has been an object of interest and a goal for exploration for many years. It has now been considered as a major stepping stone towards the exploration of Mars too. This is due to the many advantages that the Moon offers, such as its strategic orbit and base of operations for planetary exploration - it is a relatively closeby 'test ground' and can be seen, in many aspects, as an even harsher environment than what the future humans on Mars will experience. The Earth's only natural satellite has a variety of useful assets and resources for both human and technological usage, such as regolith, minerals, and quite possibly even large water reserves. Robotic exploration has been key in evaluating the Moon's potential. For example, the discovery of hydrogen-rich rocks, hydrated minerals, and signs of water on the Moon was only possible with the help of spacecraft, such as NASA's Clementina, Lunar Prospector, and ESA's SMART-1 scanning the lunar surface. However, to confirm their hypotheses and establish precise quantities, scientists need to directly measure and investigate these resources in promising geological locations, for instance lunar craters.

Operations: To safely explore these regions, engineers and scientists need to develop precision-landing capabilities, whilst also assessing the potential hazards for both the lander and the lunar surface itself. Some hazards of landing in the targeted craters include the damage caused by the engine's hot and powerful exhausts, and possible contamination from organic matter from Earth. According to ESA, an alternative option would be to land near a crater or on a crater rim and use robotic assets to reach and descend into the crater. This would minimize the aforementioned risks, however, it could carry more risks for crewed missions. Before such landings are attempted, improvements in space exploration protocols must be developed to safeguard future missions and crew.

In order to select the best candidate technologies for these missions, it is vital to understand the conditions and requirements that each project will demand. For instance, it is known that the Moon's surface contains regions known as lunar maria (large basaltic plains or 'magma oceans' - a result of ancient volcanic eruptions), which can result in extremely harsh and uneven surfaces. Other challenges lunar activities face

are extreme temperature variations; radiation exposure; uneven, limited or even a complete lack of solar lighting; and delayed and intermittent communication. Even well-established concepts, such as wheeled/tracked rovers, can only tackle a few of those lunar characteristics, but they have paved the way for new concepts to emerge.

Robotic Exploration: Experts have studied a wide range of robotic assets, which include walking, hopping, and rolling rovers, cableways, tethered 'tumbleweeds', jet-engine operated drones, and harpoons. Many of these robotic exploration concepts focus also on more specific exploratory tasks; where flying and hopping vehicles often focus on visiting multiple craters or other high-relief terrains, some of the tracked, tumbling, or walking rovers focus on the exploration of subsurface cavities, such as lava tubes. Even though most of those techniques have fundamentally different operating principles, but are designed to address the same goal: lunar exploration.



Fig.1: An example of a walking rover: The Lunar Zebro assisting during one of the CHILL-ICE I mission EVAs in Iceland, 2021.

Robot-human interfaces: Another challenge of lunar and planetary geological exploration is the interaction between such technologies and how humans can operate and collaborate with those instruments. Crater and lunar lava tube exploration, sample-taking and surface exploration are some of the mission objectives that will be tackled during future lunar missions. However, the limited communication, visibility constraints and limited grip/motion with extravehicular (EVA) suits pose many threats to space

missions and need to be developed further. Analog missions are an ideal opportunity to test these interactions and develop customs to enable successful scientific missions to the Moon and other planetary bodies.



Fig.2: Geology EVA during EMMIHS-II mission to collect samples for the effects of weathering on rock surfaces.

Although all of the presented cutting-edge solutions can be tested terrestrially under limited specific conditions, most of them still lack experimental proof of concept under the real mission conditions. A great solution to this limitation is also presented by analog space missions. These types of missions are a way to test technologies under similar conditions to the Moon or Mars, enabling experts to create new exploration and safety protocols, and foresee and tackle potential problems before the actual space mission begins.

Research bases: The specific type of analog, whether that is a terrestrial, psychological, or physiological, depends on what parameters are to be tested and vice versa; the type of analog base one should use is dependent on the research. For example, NEEMO (NASA's Extreme Environment Missions Operations) or the multiple companies offering 'zero-gravity' parabolic flights focus a.o. on human adjustments in low-gravity or environments, where bases such as D-MARS in Israel, MDRS in Utah, CHILL-ICE in Iceland, and HI-SEAS in Hawai'i focus mostly on the terrestrial analog, located in arid and/or volcanic environments akin to the Martian or lunar surface. A second advantage of utilizing the Earth as an analog is the multi-layered aspect of such an 'ICEE', or Isolated or Confined Extreme Environment'. Besides the practical and physical tests on rovers, exploration methods, development of protocols, and verifying instruments or even collecting a database of morphological, mineralogical, or chemical parameters, it takes the human and psychological influence on a missions' success into account as well. Thirdly, these types of 'analog-EVAs', can establish from a much more general or even philosophical perspective which

types of scientific research are necessary and useful in a sense to better our understanding of the other celestial bodies within our solar system. Specifically geo-related topics, such as the interpretation of a geomorphological feature, or a quick decision on which potential samples are thought to be of greater scientific value, or the definition of the route to take on an exploratory EVA can either be done by accessing a larger set or database – which due to time delay on future extraterrestrial or planetary missions is not ideal - or by human improvisation. For this, we need to become more aware of how (analog) astronauts make these decisions and how both physical and psychological parameters can influence such a decision.

Outlook: Lastly, an important, but also sometimes overlooked part of space analog missions, is the influence on the general public and the outreach that can be gained from these kinds of missions. Even though many of these terrestrial analog environments are relatively remote or closed off, they are still located on Earth. This makes the far away and 'alien' feel of extraterrestrial exploration more reachable for the general public and can spark interest amongst generations, nationalities, and disciplines – to better move forward as a species to become multiplanetary.

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