CHILL-ICE (Construction of a Habitat Inside a Lunar-analogue Lava tube): Building and testing of a deployable habitat in Icelandic lava tubes for space exploration purposes. M.V. Heemskerk[1,2,3], C.R. Pouwels[1,2], R.S. Heemskerk[1,4], S. Kerber[1,2], B.H. Foing[2,3,5,6]. [1]CHILL-ICE Core Mission Team [2]ILEWG EuroMoonMars (info@chill-ice.com) [3]VU Amsterdam, Boelelaan, 1081, Amsterdam, The Netherlands (marc@chill-ice.com) [4]HIT, Mijnbouwstraat 120, 2628 RX Delft, Nederland. [5]ESA/ESTEC, Keplerlaan 1, Noordwijk, The Netherlands (bernard.foing@esa.int) [6]Leiden Observatory

Introduction: This century, human spaceflight is expected to bring the first women and the next men to the Moon. All eyes are therefore focused on the major space agencies, such as NASA (Artemis program [1]), ESA (Moon Village [2]), CNSA (Chang'e program [3]), and Roscosmos (Lunar Orbital Station), and even on commercial companies like SpaceX. Some of these agencies are planning for a moon base to allow for longer human stays on the lunar surface, possibly even for permanent human presence [4]. Different possible scenarios for human settlements and habitation concepts are thus studied. An interesting scenario is to utilize the naturally present lunar lava tubes that provide an excellent combination between protection from micro-meteorites and radiation, structural support and thermal insulation, and ample unique research opportunities. Therefore, more research in development of these types of subsurface habitats needs to be conducted.

CHILL-ICE is a EuroMoonMars mission campaign with the main objective to deploy an affordable, efficient, and reliable habitat concept in an Icelandic lava tube within eight hours. The eight-hour time requirement is based on the limited amount of oxygen astronauts will have during an EVA. Therefore, the key objective is to study the main features of such a scenario for a lunar settlement.

Lava tube Scenario: In space exploration, lava tubes offer very interesting options for the first human habitat on the Moon, because they provide free protection from micrometeorites, radiation and regolith dust. Furthermore, in lava tubes the temperature is considered to be approximately constant at around -20°C (-4°F)[4]. This reduces the fatigue of structures reducing the complexity and weight of buildings.

Lastly, according to several studies [7], lava tubes are deposits of numerous resources due to its naturally pristine environment. These could be extremely useful for the survival of humans outside the Earth, such as the different states of water and the possibility to find microbiological life or fossils thereof.

Mission Overview: The CHILL-ICE mission [8] will take place in the second half of May, 2021. Set in the Surtshellir-Stefanshellir cave system in the Hallmundarhraun lava flow located in the Western part of Iceland, the core mission will take 10 days and will involve three distinct teams, and two groups of analogue astronauts. These teams will work to support all aspects of the mission (analogue astronauts, Mission Control, remote support, local support, outreach activities, etc.). There will be two crews with three experienced analogue astronauts each, including an all-female crew. These two crews will have the main task to build the habitat in the lava tube in less than eight hours and stay there for a total of nearly two full days (46 hours). During this period, they will test habitat features and carry out experiments inside and around the lava tubes in brief research EVA's.

The main objectives of the CHILL-ICE mission are:

- To design a simple, affordable and reliable habitat to be located in lava tubes.
- To investigate the feasibility of the construction of this habitat in less than 8 hours.
- To test habitat systems (Electrical Power System, Communication system, ECLSS).
- To test instruments and equipment (rovers, drones, robots, etc.) in a lunar-analogue field terrain.
- To study lava tube structures, geochemical compositions and stratigraphic mineralogy.
- To involve the local and international public in space related projects and improve the Icelandic Space Sector.

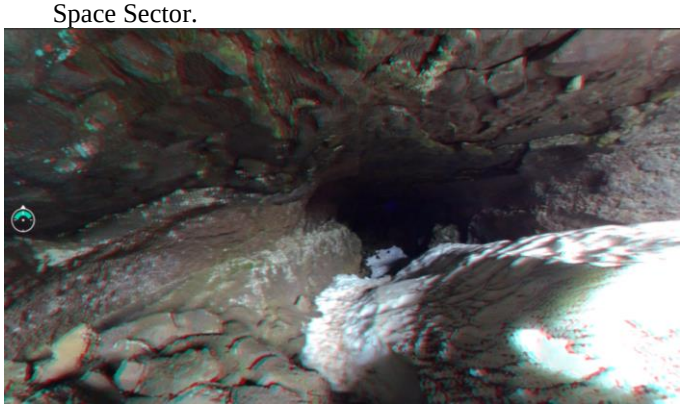

Fig. 1*: Looking towards ESE, a 3D 180º view of the inside of the Stefanshellir lava tube in Iceland. Water ice (bottom right) would be a great find on the Moon, but forms an obstacle during the CHILL-ICE mission).* Source: M. Heemskerk, 2020.

The management of the mission is supported by numerous stakeholders, who give the CHILL-ICE core team financial funds, equipment and instruments, and experience in mission organization. The main partners are: EuroMoonMars, ILEWG, ESA, Space Iceland, 4th Planet Logistics, Reykjavik University, VU Amsterdam, Wilson School of Design Canada (KPU), Lunar Zebro, Astroland Interplanetary Agency, Icelandic Speleological Society (Hellarannsóknafélag Íslands).

Preparatory missions: Due to the complexity of this mission, two scouting missions were organized in September 2018 and in June/July 2020 [7]. These missions had the objectives to identify the most suited lava tubes, establish a local network and gather national support, and to examine aspects related to the accessibility, safety, cave dimensions, and Moon-like aspects. Both were relatively short missions (5-6 days), but have been proven successful and efficient, and led to the plan of the core mission outline of today.

Future Work: With the work and collaborations for the upcoming mission, an international network between universities, research centers, and industry partners will be established. This network has the possibility to promote space related activities at an international level for STEM education and research. After this initial proof-of-concept mission, CHILL-ICE will develop a more permanent habitat that could host several missions per year during the most accessible months, and perhaps even long-duration missions during the winter months, when accessibility is reduced.

The results, comprising of data, written reports, and feedback, will be published and shared with the scientific community, universities and the general public by means of publications, workshops, interviews, and articles.

Lastly, one of the focus points for CHILL-ICE after this upcoming campaign, is to get not-directly-space-related companies involved in the (inter)national space sector. This comes from two motivations; to integrate additional non-space designed objects in exploration and research campaigns beyond the Earth, and to promote the development of new products for space exploration purposes and for utilization on Earth.

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