An endorsement to utilize terrestrial analogs as support for the upcoming Artemis missions.

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Introduction: The global exploration roadmap (2018) shows an international collaboration, with programs such as Artemis, to achieve human outposts in the solar system. The focus of these programs, in the next era, will be tied to (commercial) space stations, the Moon and Mars. Currently, Artemis is scheduled to land two astronauts on the lunar surface by 2025 [1]. To achieve this, multiple missions have been established, such as; Orion, Gateway, the Human Landing System (HLS) and future lunar (commercial) outposts. In this abstract, the focus lies on analog preparation benefits for the Orion module and Gateway space station. Even with the upcoming technology of reusable landers, space is still known as a high risk, high cost sector. Terrestrial analogs can be very useful to mitigate risks for these challenging missions. For example, to prepare and train the first Apollo astronauts for the Moon, analog locations on Earth with similar geological environments (Iceland and Hawaii) were used. During an analog campaign, operations can be conducted, such as: rover, robotics, spacesuit testing, space walk training, medical emergencies, geology sampling and more [2]][3][4].

In addition, and maybe even more importantly, analogs can map the psychological stressors, such as: isolation, crew cohesion, communication, closed confinement, impact of architecture (color), lack of access to fresh foods and nutrients, and other factors [5][6][7][8][9][10]. Furthermore, analog missions show an advancing inclusion and diversity of genders and cultural background, as often it is a collaborative venture between a myriad of individuals and groups. This is among others shown by the EMMIHS-II, CHILL-ICE and SENSORIA-I missions with the majority or all of the analogue astronauts involved being female [21][22].

Orion module: Orion (officially Orion Multi-purpose Crew Vehicle) is a partially reusable crewed spacecraft developed as part of NASA's Artemis Program [11]. The Orion Capsule aims to support crewed activities within and beyond Earth Orbit [12], and aims to support future missions to the Moon and Mars. In total, NASA has commissioned six Orion spacecraft, with options for another six if required [14]. The first uncrewed flight, Artemis 1, is scheduled for mid-2022 and the first crewed flight, Artemis 2, is scheduled for 2024 [13]. A number of Gateway resupply missions have also been proposed utilizing the Orion capsule [14], allowing for equipment, experiments and personnel to travel from the Earth to the orbiting station. During development, diverse Orion analogs were used to simulate a variety of functions. One noteworthy example is the Space Vehicle Mockup Facility (SVMF) in the Johnson Space Center [15]; this center contains numerous replicas of spacecraft, including a full-scale Orion capsule. This has been essential for preparing for upcoming flights, allowing designers to develop and assess interior layouts, and allowing astronauts to practice tasks, such as intro-vehicular maintenance, airlock operations, and communication with ground control [16]. Without analog mock-ups and missions, the window for error for the Orion module and other upcoming human spaceflight missions drastically increases.

Gateway is a spaceship that will be operated in the vicinity of the Moon, enabling distant human space missions, and offering a staging post for missions to the Moon and Mars. From the Moon to the Gateway, an approximative five-day trip will allow the pick-up of supplies and astronauts. Communication will also be relayed from the Gateway and it will serve as a scientific research base. According to the European Space Agency (ESA), the Gateway will be made up of the following modules: a service module, a communication module, a connecting module, an airlock for extravehicular activities (EVAs), living quarters and an operational station. Occupancy of the Gateway will be up to 90 days at a time, since the Gateway's first module is set to launch with the second Artemis mission using Orion. Analogue space missions are of tremendous assistance for the development of the Gateway. Entire missions could be simulated in analogue bases with the following perks:

- Testing of the robotic arm (control, structure) into a pool to simulate lower gravity and maniability.
- Testing of docking systems of the station with cargo spaceships in a dynamic system (ex: in a pool - the lack of gravity will provide similar structural conditions and corrosion). This will train astronauts and remote pilots, while feeling similar working conditions as in space (fatigue and a need to focus).
- Testing of complete crews for 90 days or less: analogue space missions could train the most

optimal team on Earth, and thus provide health and psychological data on a specific crew, and possibly increase the success of missions conducted by specific teams of astronauts.

- Life support could be tested in the habitats and any additional supply would have to be delivered using the docking mechanisms and spaceship, thus providing more isolation realism to analogue astronauts inside the base.
- Testing of scientific experiments: this would provide insight on the equipment needed for the experiments performed in the Gateway and the training required by astronauts. Poor laboratory protocols can be dangerous and damage experiments, and missing equipment can ruin experiments. In addition, performing the experiment in an analogue environment provides insight for its duration, thus improving flight plan reliability.

Although there is a lot of data on astronaut psychology, the remote nature of the Gateway (further away than the Moon) could provoke strong psychological reactions in astronauts. Analogue space missions where communications are delayed, any food, water or other external supply is accessible at given dates (date which could be delayed for simulation purposes) and through a docking mechanism would improve the remote feeling of the base and provide insightful psychological data. It could highlight possible problems of the Gateway, such as the maintainability of the robotic arm in conditions of lower focus [17][18][19][20][21][22].

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References:

[1] The global exploration roadmap, ISECG, (2018). [2] Life and Research at SouthPole Moonbase: EuroMoonMars Campaigns Results 2019-2020 Foing, B. et al (2021) 2021LPI....52.2502F. [3] EMMIHS-2 Analog Moonbase Viewpoint And Results ─ An Engineering Outlook at the Second Euro-MoonMars IMA HI-SEAS 2019 Campaign Castro Nunes, Ana et al; (2020) 2020EPSC...14.1110C. [4] The Second EuroMoonMars IMA at HI-SEA Field Campaign: An Overview of The EMMIHS-II Analog Mission to the Moon. Musilova, Michaela et al;. (2020) 2020EPSC...14.1020M. [5] Personalized Dietary Plans And Health Effects On Astronauts In Extra-Terrestrial Habitats. Chappuis, Johanna et al; (2020) 2020EGUGA..2220628C. [6]Food for Extra-Terrestrial Astronaut Missions on Native Soil. Pouwels, Charlotte et al; .(2020) 2020EGUGA..2220507P. [7] The Human Factors of Additive Manufacturing on Human Extra-Terrestrial Missions. Kerber, Sabrina et al; (2020) 2020EGUGA..2220496K. [8] Semi-privacy and Color Application as Elements of Habitability in Concept Designs for Extra-terrestrial Habitation. Kerber, Sabrina et al; (2020) 2020EGUGA..2218245K. [9] Small rover exploration capabilities. Salotti, Jean-Marc et al; (2015) 2015AdSpR..55.2484S. [10] A wide variety of putative extremophiles and large beta-diversity at the Mars Desert Research Station (Utah). Direito, Susana O. L et al; (2011) 2011IJAsB..10..191D.[11] Preliminary Report Regarding NASA's Space Launch System and Multi-Purpose Crew Vehicle (2011) https://www.nasa.gov/pdf/510449main_SLS_MPCV_90-day_Report.pdf [12] NASA ESD set key Orion requirement based on Lunar missions (2021) Bergin, Chris;https://www.nasaspaceflight.com/2012/07/nasa-esd-key-orion-requirement-lunar-missions/ [13] NASA targets February launch for Artemis 1 moon mission (2021)Clark,Stephen;https://spaceflightnow.com/2021/10/22/nasa-targets-february-launch-for-artemis-1-moon-mission/ [14] NASA awards long-term Orion production contract to Lockheed Martin (2019) Foust, Jeff https://spacenews.com/nasa-awards-long-term-orion-production-contract-to-lockheed-martin/ [15] Extreme Makeover—Space Vehicle Mockup Facility (2012) https://www.nasa.gov/centers/johnson/home/extreme_makeover_svmf.html [16] Space Vehicle Mockup Facility (SVMF) (2013) https://www.nasa.gov/centers/johnson/pdf/748457main_FS-2013-Space%20Vehicle%20Mockup.pdf [17] https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/Gateway [18] https://www.nasa.gov/gateway[19] What We Know About Team Dynamics for Long-Distance Space Missions: A Systematic Review of Analog Research, Suzanne T. Bell, Shanique G. Brown and Tyree Mitchell [20] Dynamic testing of docking system hardware, Wade D. Dorland, NASA [21] Musilova, M. et al; (2020), International MoonBase Alliance missions at HISEAS, Vol. 14, EPSC2020-1035, Europlanet Science Congress 2020 [22] Musilova, M et al;. (2019), Analogue research performed at the HI-SEAS research station in Hawaii, Geophysical Research Abstracts, Vol. 21. 2019.