THE HUMAN FACTORS OF ADDITIVE MANUFACTURING ON HUMAN EXTRA-TERRESTRIAL MISSIONS

S. Kerber[1,2,7]

Co-authors: Dr. M. Musilova[2,3,4,8], Prof. B. H. Foing[2,5,6,9]
[1] International Moonbase Alliance (IMA), United States, [2] ILEWG EuroMoonMars programme & EMMIHS (EuroMoonMars-International Moonbase Alliance- HISEAS), [3] International Moonbase Alliance (IMA) & Hawai´i Space Exploration Analog and Simulations (HI-SEAS), United States [4] Institute of Robotics and Cybernetics, Faculty of Electrical Engineering and Information Technology STU in Bratislava, Slovakia, Slovak Organisation for Space Activities (SOSA), Bratislava, Slovakia, [5] Vrije Universiteit Amsterdam, [6] ESA ESTEC & ILEWG, Noordwijk
[7] sabrina.kerber@outlook.com , [8] musilova@moonbasealliance.com , [9] bernard.foing@esa.int

Introduction

Additive manufacturing technologies have been successfully implemented in the concept designs for human interplanetary missions for some years. They not only play an important role in the designs of future-extra-terrestrial habitats, but the benefits of 3D printing have already been successfully tested on the International Space Station (ISS). [1]

However, while such studies of in-situ manufacturing techniques concentrate heavily on applications in the area of engineering, such as replacement parts and tools, or on the potential of 3D printing sustenance, they regretfully neglect to explore the potential benefits additive manufacturing could have for the Human Factors of space exploration. [1, 2]

Based on experiments during a lunar simulation at the Hawai´i Space Exploration Analog and Simulations (HI-SEAS) habitat, this paper investigates how additive manufacturing can improve liveability in a space habitat.

Figure 1. The 3D printer, set up in the engineering bay of the HI-SEAS habitat. [3]

In order to limit payloads, there will be only highly limited allowances for personal objects and leisure time items on human extra-terrestrial missions. However, such objects are indispensable for manned space exploration, as they greatly contribute to the astronauts' mental health and psychosocial balance.

Access to a 3D printer bears the potential of a much greater flexibility and variety in personal items, and could also offer the possibility to customize leisure objects to specific needs and moods of astronauts. In addition, through the limited payloads and possibilities of recycling everyday objects, additive manufacturing technology offers the opportunity to greatly enhancing the sustainability the of any human extra-terrestrial mission.

Methodology

By assessing past and present concepts of additive manufacturing in the space industry, the paper addresses the potential implementation of 3D printing technologies as a novel concept in the area of Human Factors of space exploration.

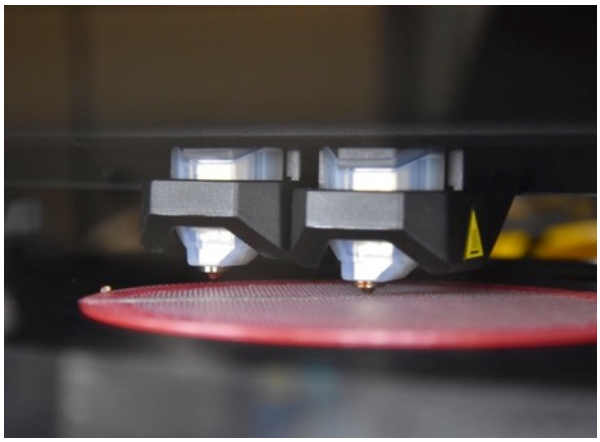

Figure 2. A dual extruder was used in the EMMIHS-II lunar simulation to support the 'Human Factors of Additive Manufacturing Study at HI-SEAS'. [4]

In December 2019 the European Space Agency's (ESA) EuroMoonMars (EMM) and International Lunar Exploration Working Group (ILEWG) initiated an analog astronaut simulation in cooperation with the International MoonBase Alliance (IMA). During this mission, titled EMMIHS-II (EuroMoonMars IMA HI-SEAS, mission 2), a crew of six analog astronauts lived, worked and researched at the HI-SEAS Mars/Moon habitat in a lunar simulation. As crew engineer and space architect, the author of this paper was in the unique position to conduct the *Human Factors of Additive Manufacturing Study at HI-SEAS,* which investigated the potential of accessing additive manufacturing techniques for the crew's benefits.

With the use of dual extrusion 3D printing machine personal items for the analog astronauts' leisure time activities, as well as engineering tools, were printed and their effects on the crew evaluated in a comparative survey.

Psychological effects, changes in mood and work effectiveness and the possibility to create and maintain a connection to Earth by 3D printing seasonal objects and decorations, were assessed.

Figure 2. Besides engineering items and personal objects, 3D printing seasonal decorations and tools can help maintain a connection with Earth on long-duration space missions. [5]

The study delivered positive results about the use of additive manufacturing from a Human Factors point of view, as well as the confirmation of the use in engineering. It has shown, that giving a crew the option of choosing what leisure time items they want manufactured from a pre-selected pool of files, increases the positive effects the usage of these objects has. Furthermore the study has proven how valuable 3D printing technologies can be in order to maintain a connection to Earth by supporting the upkeep of seasonal and cultural traditions. The results open up the possibilities for further studies of the Human Factors of additive manufacturing during future analog simulations, like EMMIHS-III.

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[3] The EMMIHS-II 3d printer. Picture credit: S.Kerber (2019).

[4] The dual extrusion system. Picture credit: S.Kerber (2019).

[5] 3d-printed seasonal decorations during Christmas time at the HI-SEAS habitat. Picture credit: S.Kerber (2019).

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