22nd IAA SYMPOSIUM ON HUMAN EXPLORATION OF THE SOLAR SYSTEM (A5)
Human and Robotic Partnerships in Exploration - Joint session of the IAF Human Spaceflight and IAF Exploration Symposia (3-B3.6)

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ROBOTIC CONSTRUCTION & PROTOTYPING OF A 3D-PRINTED MARS SURFACE HABITAT

Abstract

Team SEArch+ (Space Exploration Architecture)/Apis Cor won first place in Construction Level 1 (slab durability test), first place in Construction Level 2 (hydrostatic or seal test), fourth place in Virtual Design Level 1 (60% design), and first place in Virtual Level 2 (100% design), within NASA's Phase 3 Centennial Challenge for a 3D-Printed Habitat on Mars. The team won the greatest number of individual levels at the highest success rate within the competition, which took place from February 2019 – May 2019. Systems for large scale additive manufacturing are envisioned for robotic precursor missions which would build infrastructure prior to the arrival of crew. Part of this effort will include autonomous construction of in-situ resource utilization (ISRU) surface habitats on the Moon and Mars. The Construction Level submissions to the 3D-Printed Habitat Challenge demonstrate early experimentation in the robotic placement of habitat elements within a 3D-printed structure, while limiting human interventions as best as possible to simulate risks associated with communication latency and limited bandwidth in a future mission to Mars. Future ISRU surface habitats will incorporate precision manufactured elements such as windows and apertures, hard-shell modules for ECLSS and telecommunications, airlocks, structural reinforcement, as well as integrated sensor networks that will need to be autonomously integrated and/or placed within the 3D-printed structure. While none of the winning Challenge submissions exhibited autonomous decision-making capabilities let alone managed to execute submissions without numerous human interventions throughout the construction process, it is clear that much like early examples of automation within the architecture, engineering and construction (AEC) industries today, that human-robotic teaming will be a significant area of future research within a comprehensive concept of operations for 3D-printed surface habitats. The most necessary application for future work will be to incorporate robotic actions within building information modeling (BIM) workflows and a BIM model. Because autonomous 3D-printing systems must coordinate and function in real-time to integrate not only habitat elements launched from Earth but also ISRU materials handling equipment and excavation machinery within a strictly defined construction sequence, integration of robotic support with 3D-printing construction systems is an area of research needing much development.

Keywords: 3D-Printing, Autonomous Construction, Human Robot Collaboration, Mars Habitat, Surface Habitat