On The Development of Additive Construction Technologies for Application to Development of Lunar/Martian Surface Structures Using In-Situ Materials

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For long-duration missions on other planetary bodies, the use of in situ materials will become increasingly critical. As man's presence on these bodies expands, so must the breadth of the structures required to accommodate them including habitats, laboratories, berms, radiation shielding for natural radiation and surface reactors, garages, solar storm shelters, greenhouses, etc.

Planetary surface structure manufacturing and assembly technologies that incorporate in situ resources provide options for autonomous, affordable, pre-positioned environments with radiation shielding features and protection from micrometeorites, exhaust plume debris, and other hazards. This is important because gamma and particle radiation constitute a serious but reducible threat to long-term survival of human beings, electronics, and other materials in space environments. Also, it is anticipated that surface structures will constitute the primary mass element of lunar or martian launch requirements. The ability to use in situ materials to construct these structures will provide a benefit in the reduction of upmass that would otherwise make long-term Moon or Mars structures cost prohibitive. The ability to fabricate structures in situ brings with it the ability to repair these structures, which allows for self-sufficiency necessary for long-duration habitation.

Previously, under the auspices of the MSFC In Situ Fabrication and Repair (ISFR) project and more recently, under the joint MSFC/KSC Additive Construction with Mobile Emplacement (ACME) project, the MSFC Surface Structures Group has been developing materials and construction technologies to support future planetary habitats with in situ resources. One such technology, known as Contour Crafting (additive construction), is shown in Figure 1, along with a typical structure fabricated using this technology.


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Figure 1 – Contour Crafting Machine at NASA/MSFC and Typical Fabricated Structures

This paper will present the results to date of these efforts, including development of novel nozzle concepts for advanced layer deposition using the Contour Crafting process. This process, conceived initially for rapid development of cementitious structures on Earth, also lends itself exceptionally well to the automated fabrication of planetary surface structures using minimally processed regolith as aggregate, and imported binder material or binders developed from in situ materials. This process has been used successfully in the fabrication of construction elements using lunar regolith simulant and Mars regolith simulant, both with various binder materials.

These binder materials have resulted from extensive evaluation and include both “imported” binder materials that might be launched from Earth as well as some binder materials that can theoretically also be derived from existing regolith materials. They were chosen to 1) reduce penetrating radiation as much as possible, primarily with hydrogen-bearing polymers, 2) attempt to provide an air-tight structure, 3) sufficiently mix and adsorb to regolith grains for strength, 4) maximize tolerance to day-night thermal cycling, 5) possibly increase electrical conductivity to dissipate any accumulated static charge, and 6) ease their application on planetary surfaces (specifically, the accommodation of reduced atmosphere and lack of heat sinks). Some of these materials have been tested with respect to radiation mitigation, micrometeorite resistance, and resistance to larger, slower-traveling pieces of regolith impinging on the surface, simulating nearby launch and landing activities. Conceptual designs for a Continuous Feedstock Delivery/Mixing System (CFDMS) will also be presented and future planned activities will be discussed as well.