Greater Huntsville Section

Abstract Title: 3D Printing in Zero G Technology Demonstration Mission: Summary of On-Orbit Operations, Material Testing, and Future Work

Author(s): Tracie Prater, Quincy Bean, Niki Werkheiser, Erick Ordonez, Frank Ledbetter, Richard Ryan, Steve Newton

Affiliations: NASA Marshall Space Flight Center

Contact e-mail for primary author: tracie.j.prater@nasa.gov

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Abstract Text:

Human space exploration to date has been limited to low Earth orbit and the moon. The International Space Station (ISS), an orbiting laboratory 200 miles above the earth, provides a unique and incredible opportunity for researchers to prove out the technologies that will enable humans to safely live and work in space for longer periods of time and venture farther into the solar system. The ability to manufacture parts in-space rather than launch them from earth represents a fundamental shift in the current risk and logistics paradigm for human spaceflight. In particularly, additive manufacturing (or 3D printing) techniques can potentially be deployed in the space environment to enhance crew safety (by providing an on-demand part replacement capability) and decrease launch mass by reducing the number of spare components that must be launched for missions where cargo resupply is not a near-term option.

In September 2014, NASA launched the 3D Printing in Zero G technology demonstration mission to the ISS to explore the potential of additive manufacturing for in-space applications and demonstrate the capability to manufacture parts and tools on-orbit. The printer for this mission was designed and operated by the company Made In Space under a NASA SBIR (Small Business Innovation Research) phase III contract. The overarching objectives of the 3D print mission were to use ISS as a testbed to further maturation of enhancing technologies needed for long duration human exploration missions, introduce new materials and methods to fabricate structure in space, enable cost-effective manufacturing for structures and mechanisms made in low-unit production, and enable physical components to be manufactured in space on long duration missions if necessary. The 3D print unit for fused deposition modeling (FDM) of acrylonitrile butadiene styrene (ABS) was integrated into the ISS Microgravity Science Glovebox (MSG) in November 2014 and phase I printing operations took place from November through December of that year. Phase I flight operations yielded 14 unique parts (21 total specimens) that could be directly compared against ground-based prints of identical geometry manufactured using the printer prior to its launch to ISS. The 3DP unit

functioned safely and produced specimens necessary to advance the understanding of the critical design and operational parameters for the FDM process as affected by the microgravity environment. From the standpoint of operations, 3DP demonstrated the ability to remove parts from the build-tray on-orbit, teleoperate the printer from the ground, perform critical maintenance functions within defined human factors limits, produce a functional tool that could be evaluated for form/fit/function, and uplink a new part file from the ground and produce it on the printer. The flight parts arrived at NASA Marshall Space Flight Center in Huntsville, Alabama in April 2015, where they underwent months of testing in the materials and processes laboratory. Ground and flight prints completed the following phases of testing: photographic/visual inspection, mass and density evaluation, structured light scanning, XRay and CT, mechanical testing, optical microscopy, scanning electron microscopy, and chemical analysis. This presentation will discuss the results of this testing as well as phase II operations for the printer, which took place in June and July of 2016.

Lessons learned from the tech demo and their impacts on the design and development of the second generation 3D printer for ISS, the Additive Manufacturing Facility (AMF) by Made In Space will also be presented. In addition, progress in other elements of NASA's In Space Manufacturing (ISM) initiative such as the on-demand ISM utilization catalog, in-space Recycler ISS Technology Demonstration development, launch packaging recycling, in-space printable electronics, development of higher strength polymeric materials for 3D printing and Additive Construction by Mobile Emplacement (ACME) will also be addressed.