ISM Digital Design and Verification Database (HEOMD AES Funded)

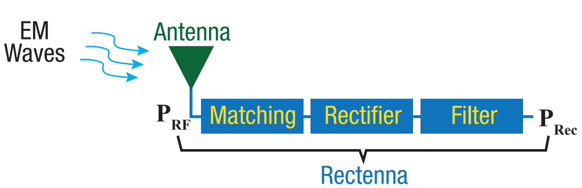
This task is led by Human Exploration and Operations Mission Directorate (HEOMD) Advanced Exploration Systems (AES). The candidate parts/systems for on-demand manufacturing must be identified and designed for 3D printing processes and materials. Whereas the printing technologies focus on "HOW" to make what is needed, a design database including vetted parts/systems for on-demand manufacturing on-orbit must be developed to define "WHAT" needs to be made. This database includes the design file or "blueprint" for the part to be fabricated, as well as all relevant data such as materials, process parameters, and inspection/verification criteria which will ultimately result in a Catalog of approved parts for on-orbit fabrication and use. The database also allows redesign of existing parts, analysis of those redesigns, and manufacturing execution management through inspection, allowing a "build record" to be developed and saved for each produced part. This activity also involves the development of new multi-material parts including polymers, composites, metals, and electronics.

ISM Design Database Development Life Support Systems Retaining Plate (Left); Logistics Reduction Urine Funnels (Right)

CANS

The Cooperative Agreement Notice (CAN) Dual Use Technology Development at NASA Marshall Space Flight Center (MSFC) is a way for In-Space Manufacturing (ISM) to use new technology development to meet specific needs of ISM through technology partnerships. ISM has utilized this program over the past few years to perform collaborative research with leading universities in specific areas such as supercapacitor development for energy storage, harvesting of WiFi for power generation, development of sensors for Structural Health Monitoring and stress sensing for Astronaut Crew Health, and for development of innovative manufacturing processes needed for In Space Manufacturing such as laser sintering of new materials.

EMI/WiFi Power Harvesting



Summary

The NASA In-Space Manufacturing (ISM) Project managed out of the Marshall Space Flight Center is working to provide capabilities for on-demand sustainable manufacturing, repair, and recycling operations during NASA Exploration Missions (transit and on-surface). One of ISM's main goals is a "Make it, Don't take it" approach. This includes testing and improving the technologies, as well as establishing the required skills, and processes that will allow it to become an industry standard.

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NP-2019-11-083-MSFC G-532938

National Aeronautics and Space Administration

ISM In-Space Manufacturing

OBJECTIVE: To develop the technologies and processes which will enable on-demand manufacturing capability during long-duration space missions.

For long-duration space travel to be feasible, it is crucial for there to be a paradigm shift in the design and manufacturing of space architectures. In-Space Manufacturing (ISM) is a program which seeks to develop technologies for these exploration missions. ISM can provide on-demand fabrication, repair, and recycling for critical systems, habitats, and mission logistics and maintenance (both in-transit and on-surface). This can provide cost savings by decreasing launch mass. Risk is reduced by decreasing the need for pre-produced spares and/or over-designing systems for reliability. ISM is developing these capabilities by using new technologies being developed terrestrially and modifying them for use in the space environment. The International Space Station (ISS) serves as a one-of-a-kind test bed on the ISM technology development roadmap.

ISM has a task portfolio which will develop manufacturing and recycling systems and processes that will allow on-demand production of a wide array of parts and components. The ISM motto is "Make It, Don't Take It!" The project is led out of the Space Technology Mission Directorate (STMD) Game Changing Development (GCD) Office with Marshall Space Flight Center (MSFC) acting as the lead Center.

In-Space Manufacturing Technology and Material Development

3D Printing in Zero-G Technology Demonstration

The 3D Printing in Zero-G ISS Technology Demonstration was the first time that Additive Manufacturing (3D Printing) was performed in space, and was performed under a Small Business Innovative Research (SBIR) with Made In Space, Inc. (MIS). The samples were fabricated using Fused Deposition Modeling (FDM) of polymers and were returned to NASA's MSFC where they underwent extensive testing, along with the ground-printed controls, to assess if there were any differences in the parts produced in microgravity from those manufactured on earth. Results indicated that there is no significant impact of microgravity on the fused deposition modeling process. Additional testing further validated these findings.

Commander Butch Wilmore holds 3D printed container on ISS

Additive Manufacturing Facility

The Additive Manufacturing Facility (AMF) started under a NASA SBIR with MIS. The AMF was installed on the ISS in April 2016 and provides a commercial 3D printing capability to customers through the ISS National Laboratory and the Center for the Advancement of Science in Space (CASIS).NASA uses AMF through an Indefinite Delivery/Indefinite Quantity (IDIQ) contract.

ISS Additive Manufacturing Facility

Multi-Material Fabrication Laboratory (FabLab)

The Fabrication Laboratory (FabLab) project seeks to develop a larger scale space station facility for multi-material manufacturing which also include inspection capabilities. Systems must fit into an EXPRESS rack and are limited to peak power consumption of 2000 Watts, a weight of 260 kg, and a volume of 0.45 cubic meters. The phase A effort is focused on development of ground-based prototype systems and technology demonstration. Subsequent efforts will mature the FabLab system to a flight demonstration on ISS, which includes 3D printing of metals on-orbit, in the early 2020s.

In-Space Manufacturing SBIRs

Common Use Materials SBIRs

Logistics analyses show the dramatic impact of a recycling capability for reducing initial launch mass requirements for long-duration missions. Current packaging materials for ISS represent a broad spectrum of polymers such as low density polyethylene (LDPE), high density polyethylne (HDPE), polyethylene terephthalate (PET), Nylon, and polyvinyl chloride (PVC). ISM is collaborating with ISS packaging and Logistics Reductions teams to identify materials and processes to provide common use materials that can initially be used for packaging and then recycled into useable feedstock for fabrication of parts during missions. Under a small business innovative research (SBIR) contract, Tethers Unlimited Inc. developed Customizable Recyclable ISS Packaging (CRISSP), which is a recyclable foam packaging made from thermoplastic materials using FDM. The packaging is created with custom infill profiles for the foam to yield specific vibration characteristics or mechanical properties. Cornerstone Research Group (CRG) developed a Polyethylene-based thermally reversible material which can be processed into films and foams and recycled into filament for 3D printing. The RVT material developed by CRG has strength and modulus values comparable to or exceeding base thermoplastic materials while maintaining a viscosity that is compatible with fused filament fabrication (FFF) systems.

Vulcan SBIR:

The Vulcan effort from Made in Space (MIS) uses a welding process to additively manufacture parts. The wire-fed process is compatible with virtually every aerospace grade metal material available in the form of welding wire. In a phase II-E effort, MIS is developing an integrated, ground-based prototype of Vulcan which includes the following subsystems: the additive manufacturing unit, a CNC mill for finish machining, an environmental control unit to manage and collect all chip debris, a polymer manufacturing head based on the Additive Manufacturing Facility (AMF), and a robotic capability to flip the part for machining and remove it from the build plate.

Left image is the rendering of the Vulcan Unit payload in a double locker and the Right image is an example of a metal part produced with the system. Images from Made in Space.

AMARU SBIR:

AMARU from MIS is an In Situ Monitoring and Process Control capability which will be integrated into the Vulcan system. AMARU integrates advanced sensor technology with a real-time data stream for part production analysis.

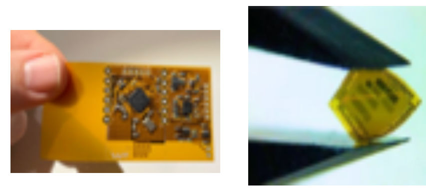
Multi-Material Fabrication with Printed Electronics

The objective of the Multi-Material Fabrication with Printed Electronics (MMF-PE) task is to develop materials and processes for on-demand printing of multiple functional materials, including printed electronics, in microgravity conditions. These materials include functional materials such as titanium and aluminum, as well as polymers and a wide array of electronic inks. This enables fabrication of hybrid parts/components, including embedded electronics, which in turn greatly increases the range of applications and uses for on-demand part production during long-duration space missions. The current areas of focus for Multi-Material Fabrication with Printed Electronics applications include: Advanced sensors for Astronaut Crew Health and Structural Health Monitoring, Radio-frequency Identification (RFID) Sensing, and Energy Storage & Power Generation.

A new, advanced flexible wireless multi-sensor wearable device is being developed and fabricated with 3D on-demand printing, for monitoring of astronaut crew health. This device will utilize a full range of on-demand 3D multi-material printing processes, new materials, and advanced sensors being developed by the ISM MMF-PE team.

Numerous collaborations with universities are helping the MMF-PE team develop a range of new technologies in printed supercapacitors for energy storage, power harvesting from Wi-Fi, new 3D printed electronic antennas, new biosensors, and advanced laser sintering processing techniques.

The technologies being developed and patented by the ISM MMF-PE team are being used by a number of companies evaluating commercial applications of the technologies. The science of In-Space Manufacturing will become the science of American industry in the coming years, as on-demand 3D multi-material printing of multiple materials becomes established in space.



Left image is a Flexible Sensor Board with High-Speed Bluetooth Low-Energy Communications and Right image is a Flexible Interposer Board with Die-mounted Microprocessor