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. This activity also involves the development of multi-material parts including polymers, composites, metals, and electronics.

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

Collaborative Leveraging Activities:

Future Engineers STEM Program

The ISM project was inspired to start a national Science, Technology, Engineering, and Math (STEM) outreach program called Future Engineers to help develop the future workforce needed for 3D printing. The Future Engineers Program is a K-12 STEM challenge made possible through a Space Act Agreement (SAA) between NASA and the American Society of Mechanical Engineers (ASME). To date, this national challenge has inspired thousands of students across the U.S. to learn meaningful design skills.

ISM 2019 X-Hab Innovation Challenge

The goals of the challenge are to develop higher strength filament feedstocks that are compatible with the standard FDM process and incorporate simulants of planetary in-situ materials (such as regolith), and/or materials that would otherwise represent nuisance/discarded materials on space missions into the filament. Two Universities are currently selected for the topic "Novel Feedstocks for In-Space Manufacturing".

SUMMARY

The In-Space Manufacturing (ISM) Project is a NASA asset managed out of Marshall Space Flight Center that is responsible for developing the capabilities to provide on-demand, sustainable manufacturing, repair, and recycling operations during NASA Exploration Missions (in-transit and on-surface). One of ISM's primary objectives with the key capabilities being developed is a ***"Make it, Don't take it"*** approach. This includes testing and advancing the desired technologies, as well as establishing the required skills and processes for the processes (such as certification and characterization) that will enable the technologies to become institutionalized.

For More Information Contact:

Ms. Niki Werkheiser 256/544-8406
NASA/MSFC
ST23
Huntsville, AL 35812

Dr. Tracie Prater 256/544-5849
NASA/MSFC
EM04
Huntsville, AL 35812

ISM
In-Space Manufacturing Project

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

Long-duration Exploration missions require a paradigm shift in the design and manufacturing of space architectures. The ability to perform In-Space Manufacturing (ISM) provides a solution towards sustainable, flexible missions (both in-transit and on-surface) through on-demand fabrication, repair, and recycling capabilities for critical systems, habitats, and mission logistics and maintenance. These capabilities provide tangible cost savings due to reducing launch mass, as well as significant risk reduction due to decreasing dependence on spares and/or over-designing systems for reliability. ISM is developing these capabilities by leveraging the highly disruptive technologies being developed terrestrially and adapting them for operations in the space environment. Thus, the International Space Station (ISS) serves as a one-of-a-kind test bed on the ISM technology development roadmap.

ISM consists of an integrated task portfolio which culminates in the development of manufacturing and recycling systems and processes that will enable on-demand production of a wide array of parts and components The ISM motto is "Make It, Don't Take It!"and 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 commercial 3D printing capability to customers through the ISS National Laboratory and the Center for the Advancement of Science in Space (CASIS), as well as manufacturing of NASA parts through an Indefinite Delivery/Indefinite Quantity contract.

ISS Additive Manufacturing Facility (AMF)

Multi-Material Fabrication Laboratory (FabLab)

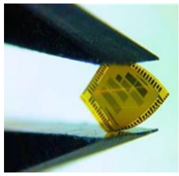
The FabLab project seeks to increase the number of printable materials (feedstock) available while improving overall manufacturing efficiency. The FabLab payload goal is to demonstrate an end-to-end manufacturing process using multiple materials including metals. This includes the capability to 3D print with metals.

The FabLab capability will be developed in three phases. The Phase A objective is to demonstrate scalable ground-based prototypes designed to be compatible with the ISS EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack and capable of remote operation from Earth. The Phase B objective is to further mature the technology towards flight qualification. Phase C will be an ISS technology demonstration to prove the printing method in consistent microgravity, define the parameters necessary for optimized printing in space, fully characterize the printed material, and fabricate usable components for the ISS. Demonstration of the FabLab on the ISS will lead to future manufacturing systems for deep space habitats and transit vehicles.

Multi-Material Fabrication with Printed Electronics

The objective of the Multi-Material Fabrication with Printed Electronics task is to develop and characterize stronger types of materials and processes including various metals, plastics, and digital/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: Radio-frequency Identification (RFID) Sensing, Flexible Sensing for Crew Health Monitoring, Structural Health Monitoring, and Power Generation.

Flexible Electronics Sensor



In-Space Recycling & Reuse Technology and Material Development:

ISS Refabricator Technology Demonstration

The "Refabricator" is an integrated 3D Printer and Recycler that demonstrates the repeatable, closed-loop process of recycling plastic materials into feedstock for additive manufacturing in the microgravity environment of the ISS. The Refabricator hardware was designed and developed by Tethers Unlimited, Inc. (TUI) using SBIR awards. This technology demonstration is a meaningful step toward a closed-loop system and demonstrates the capability to turn waste plastic and previously 3D printed parts into high-quality 3D printer filament to create new tools and materials. The demonstration uses control plastic recycled multiple times to create parts to be tested for quality back on Earth. The Refabricator was placed into service on ISS in early 2019.

ISS Refrabricator Unit

ERASMUS Phase II SBIR

ERASMUS is the next-generation integrated 3D Printer/Recycler/Sterilizer for closed-loop recycling during space missions and will result in the first-generation Exploration recycling/sterilization system. Made possible through SBIR awards to TUI, ERASMUS builds on the lessons learned from the TUI-developed Refabricator, while also incorporating the additional capability of sterilization. ERASMUS integrates a plastics recycler, dry heat sterilizer, and 3D printer to create a system that accepts previously- used plastic waste and parts, sterilizes the used materials, recycles them into food-grade and medical-grade 3D printer filament, and 3D prints new plastic implements, including those that are food and medical safe.

Printed, Recycled, and Sanitized Spoons

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 LDPE, HDPE, PET, Nylon, and 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 be recycled into useable feedstock for fabrication of parts during the mission. Using the SBIR awards, TUI and Cornerstone Research Group (CRG) are developing such materials. TUI is developing 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. CRG is focusing on the development of reversible thermoset (RVT) copolymer materials. The RVT acts as a thermally activated viscosity modifier impacting the melt properties of the material. The designs have strength and modulus values comparable to or exceeding base thermoplastic materials while maintaining depressed viscosity that makes them compatible with FDM.