In-Space Manufacturing

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Project Overview

The NASA In-Space Manufacturing (ISM) Portfolio, managed out of the Marshall Space Flight Center, is working to develop capabilities for sustainable manufacturing and the ability to repair components and infrastructure during NASA Exploration Missions (Low Earth Orbit, transit, and non-terrestrial surfaces).

Primary strategic areas include:

- **Electronics**
- **Welding/Additive Manufacturing (AM)**
- **Recycling**
- **Associated quality verification technologies**

Technical Approach

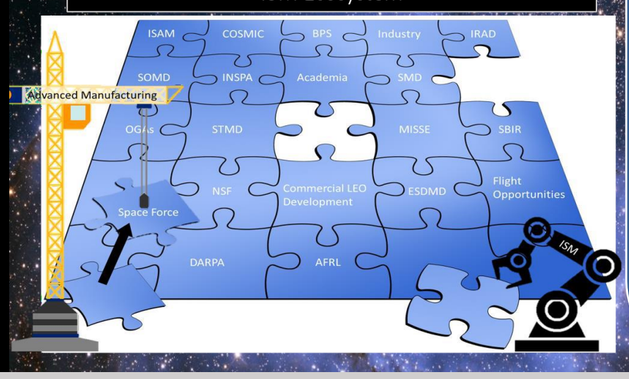
The ISM Portfolio seeks out opportunities to develop fundamental manufacturing processes for use in space through testing in increasingly high-fidelity environments (e.g. thermal vacuum chambers and parabolic flights to in-space and non-terrestrial surface demonstrations).

Technology Maturation Plans are utilized to define a clear path to the advancement of Technology Readiness Level and to link developmental goals to NASA strategy.

Infusion Plans

The ISM Portfolio identifies infusion opportunities early in the pursuit of new technology development areas by seeking out customers and partners across NASA, industry, academia, and other government agencies. Relationships are built through collaborating on projects of progressively increasing scope, budget, and schedule demands. By incorporating effective communication with partners and customers from ideation to execution, the ISM Portfolio develops and matures new capabilities that cater to end-users' needs.

ISM Ecosystem



Develop a Space Economy

Applications: High Volume Manufacturing of Goods for Terrestrial Use

- Leverage the significant advantages of microgravity
- High-Performance, low-cost microelectronics and semiconductors
- Manufacturing goods in space for Earth
- Manufacture space infrastructure for microgravity enhanced production

Focus: Semiconductors, Biomanufacturing/cancer treatments & STEM cell research, AM/Welding of Metals, Polymers, Microelectronics and Sensors

Enable Deep Space Missions

Applications: Living Sustainably on the Lunar and Martian Surfaces

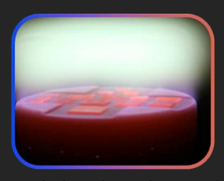
- Medical Devices and Biosensing
- Crew Tools & Engagement
- Habitats Outfitting, Towers, & Large Infrastructure
- Critical repair and EVA Aids (ex. modular excursion devices)

Focus: Enabling living and working in space to be economically sustainable → reducing operations cost and utilizing in-situ resources.

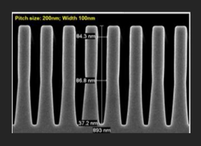
Modular Advanced ToolPlate Printer

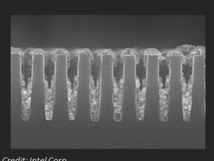
ELECTRONICS

ODME Additive Electronics: Higher Resolution and Fewer Defects in Microgravity



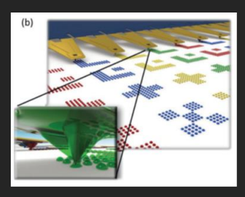
Wide bandgap diamond semiconductor





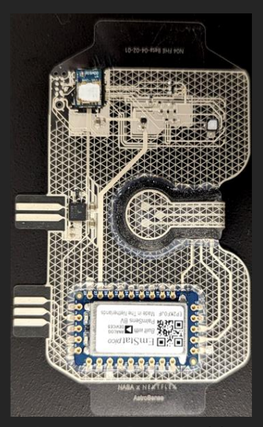
Credit: Intel Corp.

SEADS RRAM wafer "trenches" Nanodeposition on Si

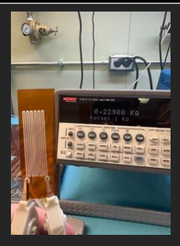


Purdue Neuromorphic Computing device

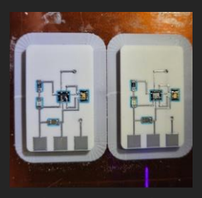
ODME New EHD Inkjet Process replaces costly CVD processes used for semiconductor memory manufacturing. Benefits include much lower cost, higher performance, and radiation hardening.



Astronaut Crew Health Wearable Cortisol Sensor



Strain Sensor Test Specimens printed at MSFC



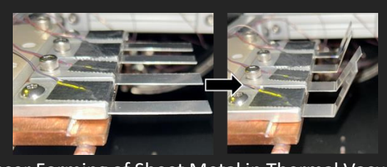
Redwire Printed CO2 Sensor Redesign

WELDING/AM

In-Space Welding Space Environment Maturation

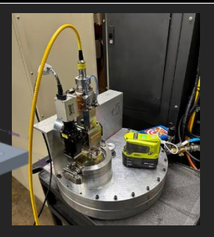
To sustainably establish infrastructure in space and on non-terrestrial surfaces, the development of in-space welding and allied processes is required.

- Large structures - such as power/communication towers, habitats, and storage tanks.
- Launch vehicle, habitat, and infrastructure repair using welding processes.
- Pursuing welding-allied processes such as cutting, drilling, forming, and additive manufacturing.

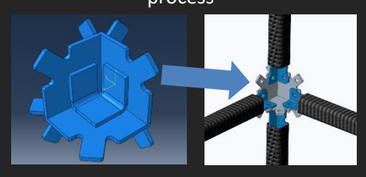


Laser Forming of Sheet Metal in Thermal Vacuum

Robotic laser welder in simulated environment as digital twin of actual process



Protoflight unit for in-space laser welding experiment



Example of innovative Snowflake joint for tall towers on planetary bodies, joined via welding

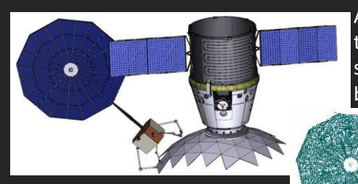
Snowflake Joint

On-demand Parts and Tools

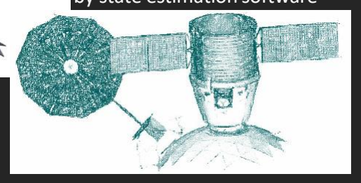
- Enabling long-duration missions
- Preventing loss of mission or life
- Providing the tools for success

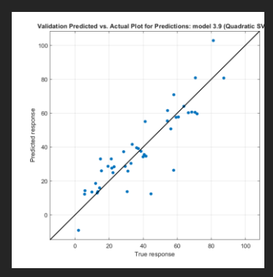
Verification Technologies

Digital Twin Workflow for ISM



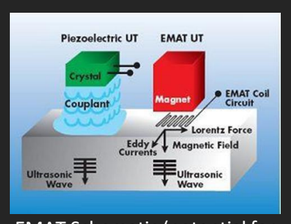
Approach and rendezvous of a tool for ISM to a structure in space as modeled and as seen by state estimation software





Machine Learning Predictions of Laser Forming

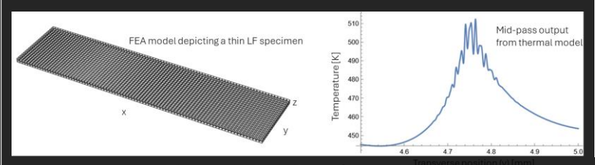
Non-Destructive Evaluation



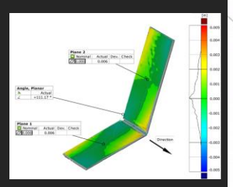
EMAT Schematic (potential for non-contact NDE)

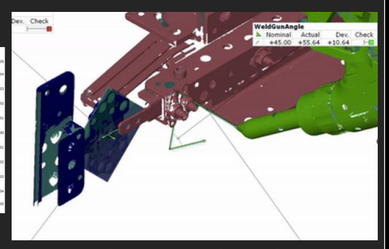
Robotic EMAT Demo

Integrated Computational Materials Engineering (ICME) tools and digital twins are necessary to enable ISM processes. Terrestrial development of manufacturing processes requires significant testing to qualify a process for mass use. The space environment, and the constraints that it creates, make it difficult to perform the number of tests that are required terrestrially. To address this challenge, a combination of ICME tools, digital twins, machine learning models, and design safety factors will need to be established.



Thermal Modeling of Laser Forming

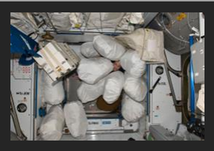




High-Resolution Imaging of Systems and Samples

RECYCLING

Recycling Metals



Repurposing and recycling waste consumables to provide higher value

Aluminum Chips

Extruded Wire

Recycling Polymers

Nylon/LDPE Air Pack

Polymer Chips