



NASA Technology Development for In-space Manufacturing Applications

Presenting: Christopher Roberts, PhD | MSFC

*Solid Freeform Fabrication
Symposium 2023*



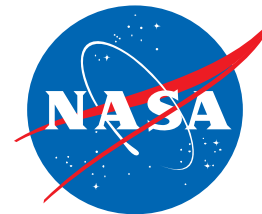
Christopher E. Roberts, Ph.D.

In Space Manufacturing Chief Engineer

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Christopher Roberts is a chief engineer at NASA Marshall Space Flight Center. He received his B.S. in Mechanical Engineering from Auburn University (2014) and his M.S. and Ph.D. in Materials Science and Engineering from the University of Texas at Austin (2016 and 2018, respectively). For the past five years, he has worked closely with the In-Space Manufacturing (ISM) team at MSFC to develop additive manufacturing technologies adapted for the unique environment of space. Chris is currently serving as the chief engineer for the In Space Manufacturing portfolio.



Why Manufacture In Space?



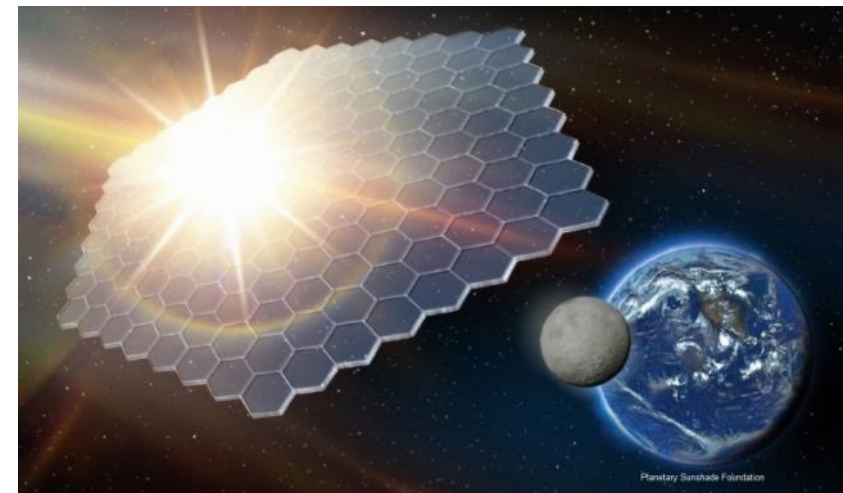
*Cargo Delivery to ISS
(image credit NASA)*



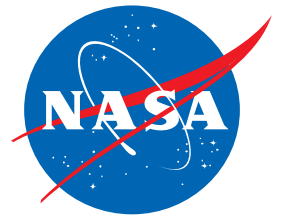
Moon to Mars Objectives (image credit Icon)



*Trash Management on ISS
(image credit NASA)*



Build objects too big or fragile to launch



Why Manufacture In Space?

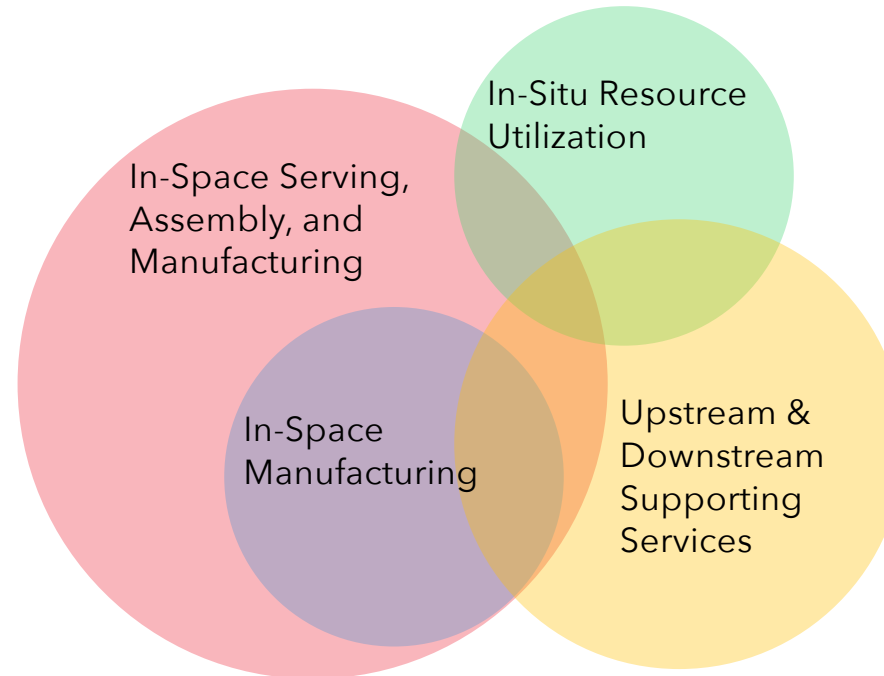


IN-SPACE SERVICING, ASSEMBLY, AND MANUFACTURING NATIONAL STRATEGY

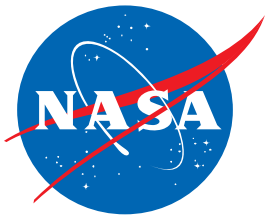
Product of the
IN-SPACE SERVICING, ASSEMBLY, AND MANUFACTURING
INTERAGENCY WORKING GROUP
of the
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

April 2022

“ISAM capabilities can create the foundation for sustainable operations and serve as a strategic enabler to spur U.S. scientific and technological innovation, ensure the freedom to operate, and preserve the use of space for future generations.”



Adapted from In-Space Manufacturing-2022 Industry Survey
Erik Kulu



What is Different?



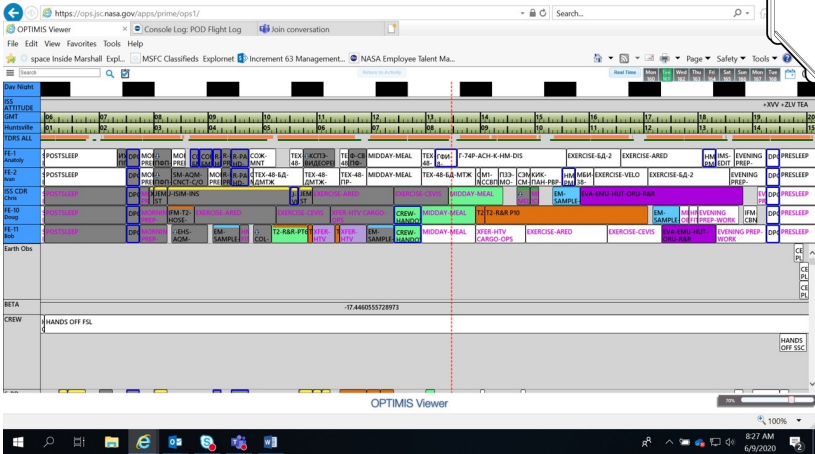
Microgravity



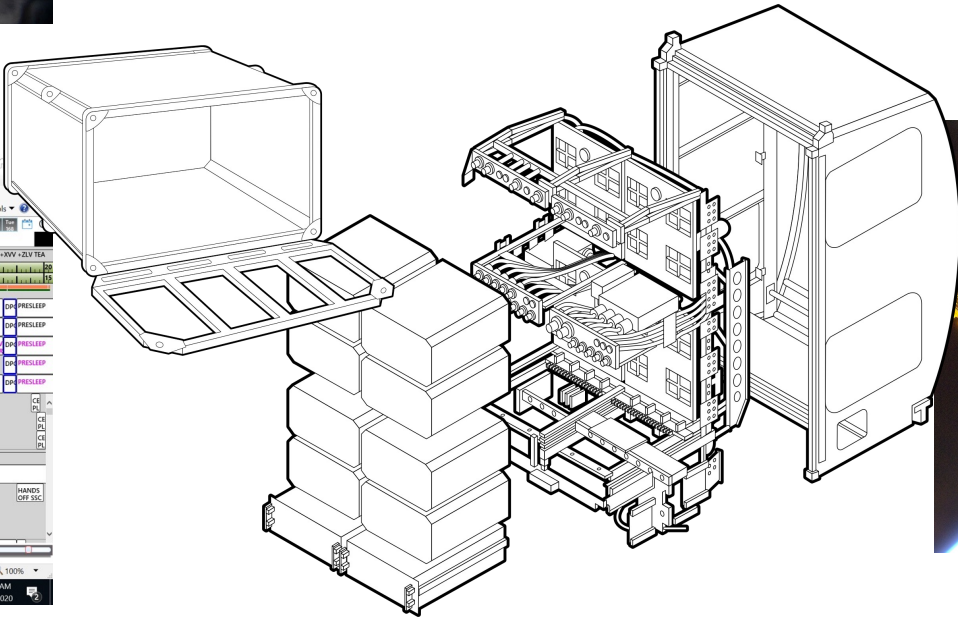
Launch Loads



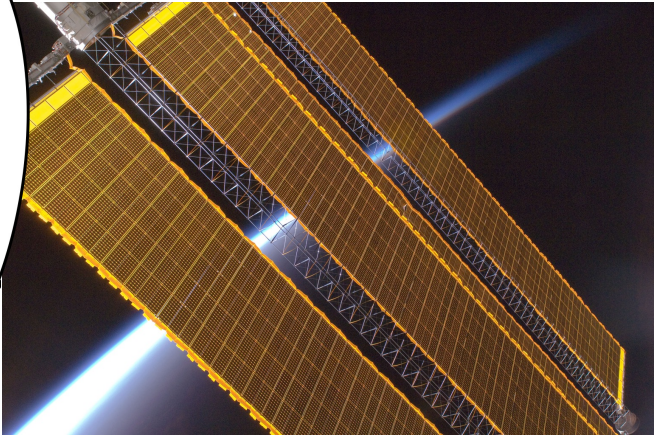
Heightened Safety Concerns



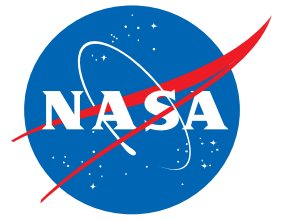
Limited Crew Time



Volume, Mass, and Interface Constraints



Limited Power



Current Status

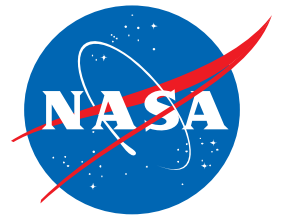
Due to changing agency priorities, budgetary concerns, and outstanding technical challenges the On Demand Manufacturing of Metals Project was canceled.

- The MSFC Science and Technology Program office is assessing alternative routes to mature additive manufacturing for in space applications.
- The multi-material fabrication laboratory (FabLab) was subsequently descoped
 - Furnace Module was deleted from the payload.
 - Printer module development continues; however, only electronics printing was maintained, which leads to

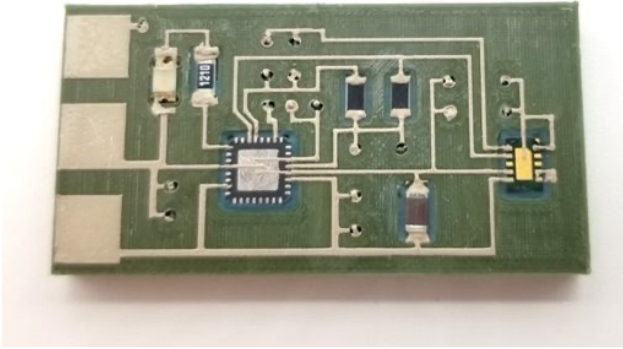
On Demand Manufacturing of Electronics (ODME) remains:

- Forward planning and reformulation is underway with a focus on the printer module and technology development





Future for In-Space Manufacturing



Additively-printed CO2 sensor



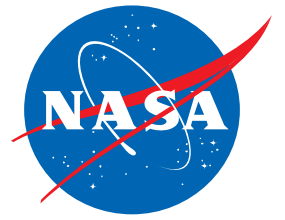
Branch Technologies Modular Outfitting Demonstrator



In Space Welding

In-Space Additive Manufacturing of Metals:

- Still listed as a known gap and technical priority



Metals Manufacturing Status at Closeout

Technical:

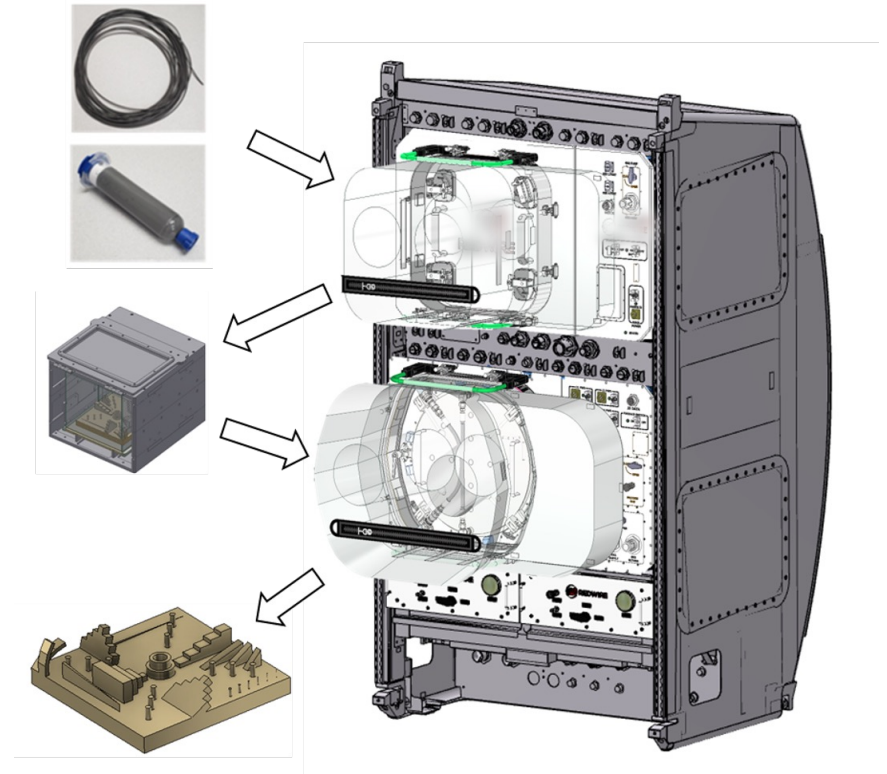
- Thermal & Power Performance approximately 250W above interface requirements at sintering temperature for Ti64

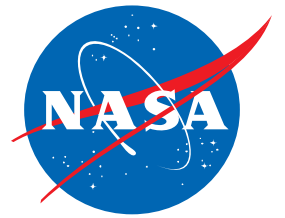
Potential Solutions:

- Hardware optimization and thermal shielding
 - Relax science requirements to below wrought values (what strength is sufficient, as opposed to what strength is ideal)
 - Lower sintering temperature for longer duration
 - Lower temperature material
 - Target future Commercial LEO Destinations with additional power
- 4.5"x4.5"x6" Build Volume
 - Completed a Phase I Payload Safety Review Panel and PDR

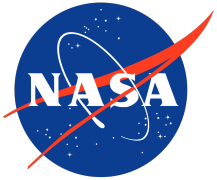
Programmatic & Strategy:

- Baselined a Technology Maturation Plan for In-Space Additive Manufacturing of Metals





Technology Maturation Plan



In Space Manufacturing (ISM) On Demand
Manufacturing of Multi-Materials (ODMM)

Technology Maturation Plan (TMP)

Prepared by the ISM Team

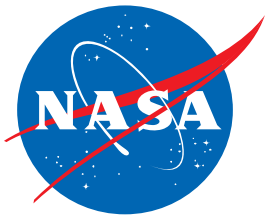
April 2023

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Objective: Document the engineering and programmatic approach to maturing On Demand Manufacturing of Multi-Materials through infusion into surface and transit applications.

Scope: Multi-materials manufacturing (polymers and metals) within a pressurized, temperature-controlled environment

- Beginning: First Generation Hardware Development
- Completion: Baselining into mission architecture



Organization



In Space Manufacturing (ISM) On Demand Manufacturing of Multi-Materials (ODMM)

Technology Maturation Plan (TMP)

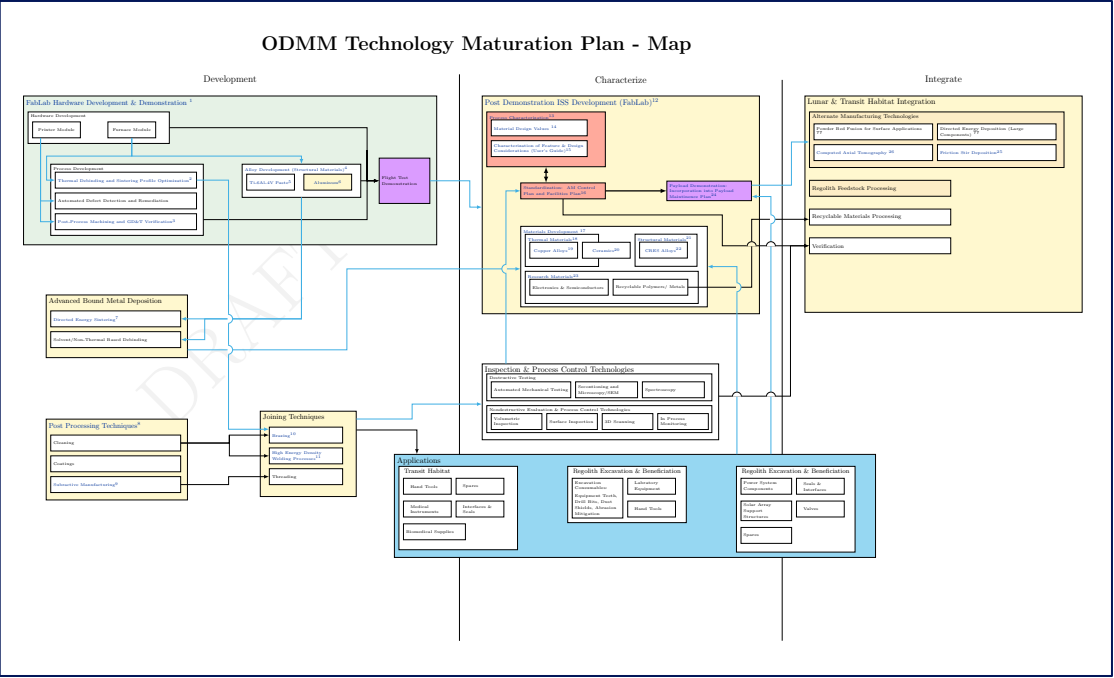
Prepared by the ISM Team

April 2023

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Technical Maturation Map: Shows interrelations between tasks and overall approach

Task Sheets: Give detail to the technical approach for each block



On Demand Manufacturing of Multi-Materials (ODMM)		
Document Title: ODMM Technology Maturation Plan	Document No: ISM-DOC-XXXX	Draft v1
	Release Date:	Page: 12 of 16

TASK SHEET 1

FabLab Hardware Development & Demonstration

[Return to Map](#)

1.1 Overview

The On-Demand Metal Manufacturing (ODMM) Project will pursue the commercial development of a hybrid (additive-subtractive) manufacturing prototype unit for demonstration aboard the ISS. A fully integrated system using Bound Metal Additive Manufacturing (BMAM), developed by Redwire, Inc., to produce titanium (Ti6Al4V) parts; this approach has the potential to expand material processing capability to other metals as well as polymers with the vision of providing a multi-material capability for future missions. The system is referred to as Fabrication Laboratory (FabLab). The primary goal of ODMM is to bring the aforementioned on-demand manufacturing system to a flight demonstration for ISS, where the feasibility of manufacturing metal parts in low-gravity can be demonstrated. This work aligns directly with NASA's 2020 Technology Tansomey for TX 12, "Materials, Structures, and Manufacturing."

The overarching goal for the ODMM project is:

- Develop and demonstrate the feasibility of a low-gravity, on-demand manufacturing system for metal parts on the International Space Station.

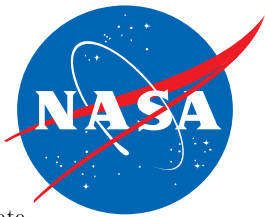
The ODMM project objectives are:

- Design, build, and demonstrate an on-demand manufacturing approach in low gravity for metal parts.
- Deliver to ISS a flight-certified, on-demand manufacturing system or systems.
- Demonstrate the manufacture of metal parts in a low-gravity environment on ISS.
- Evaluate parts made on ISS against parts produced on the ground.
- Develop physics-based models to predict processing parameters and material outcomes under low-gravity conditions for metals.

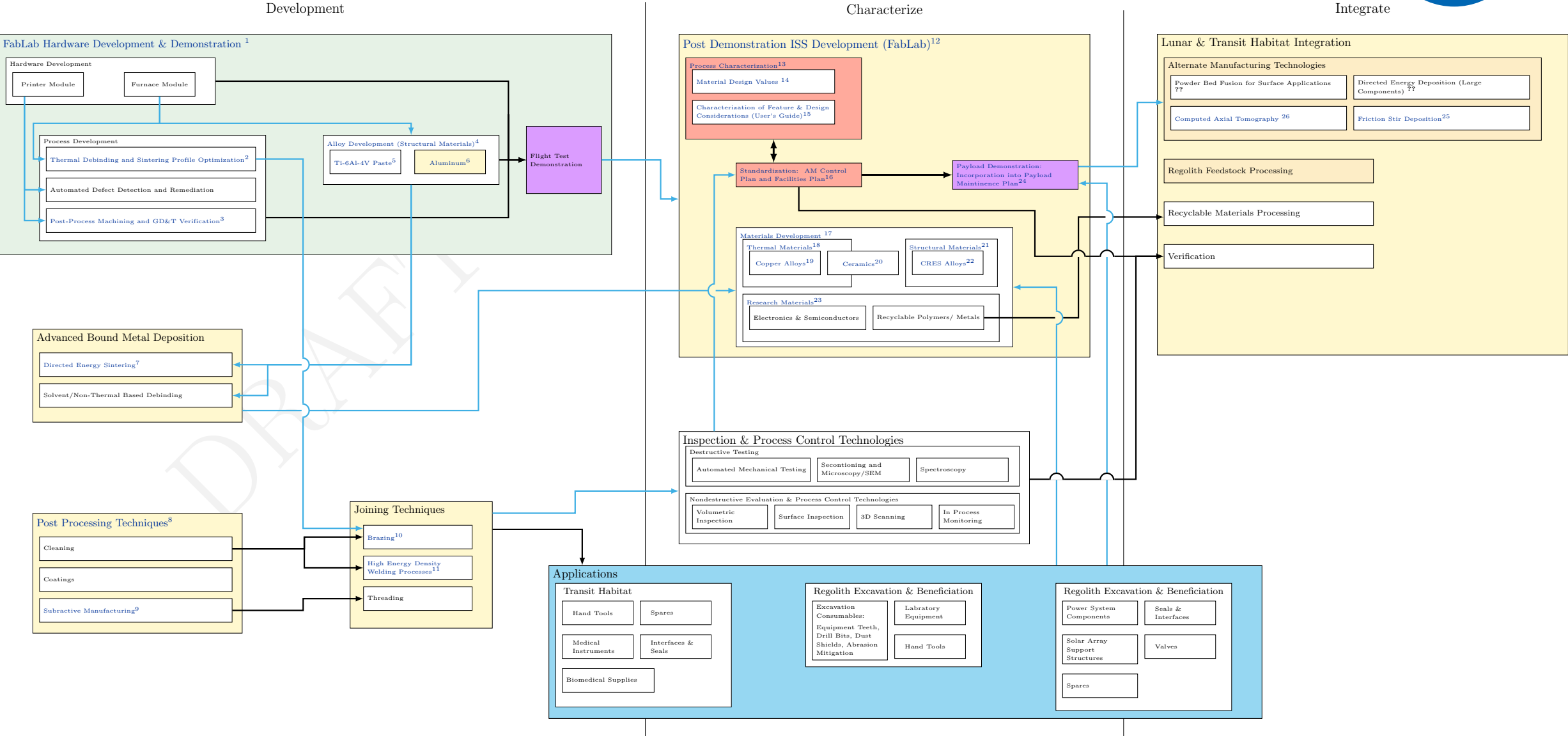
1.2 Technical Approach

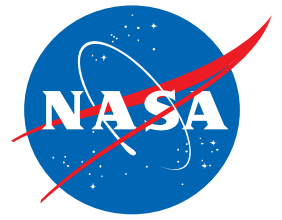
To achieve the project goal of demonstrating feasibility of an on-demand metal manufacturing system on ISS, ODMM is currently working with an industry partner to develop a system that will potentially be demonstrated

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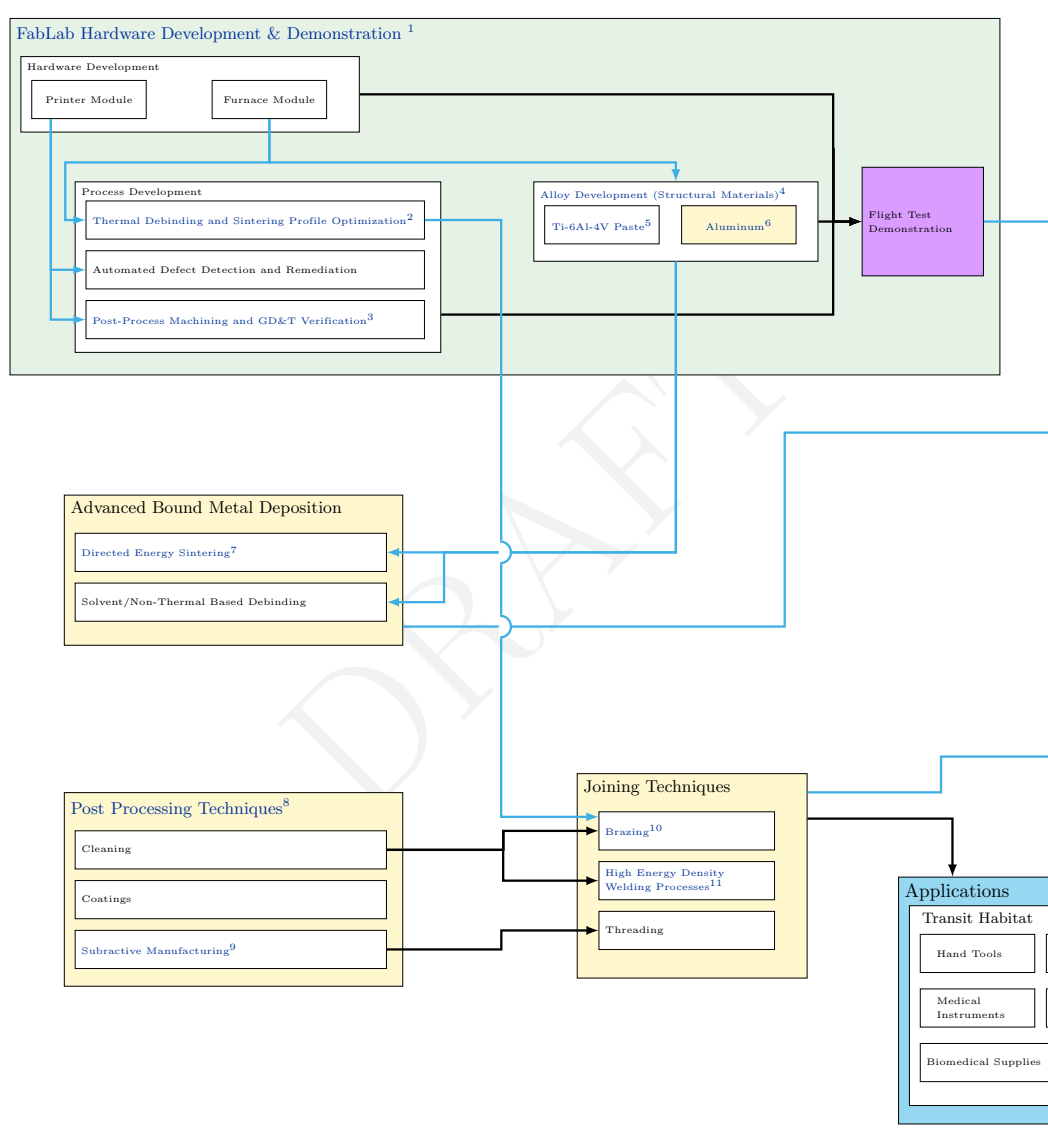


ODMM Technology Maturation Plan - Map





Demonstrate

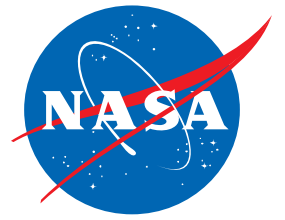


Objective: develop technology demonstrators to illustrate the feasibility of manufacturing components in space

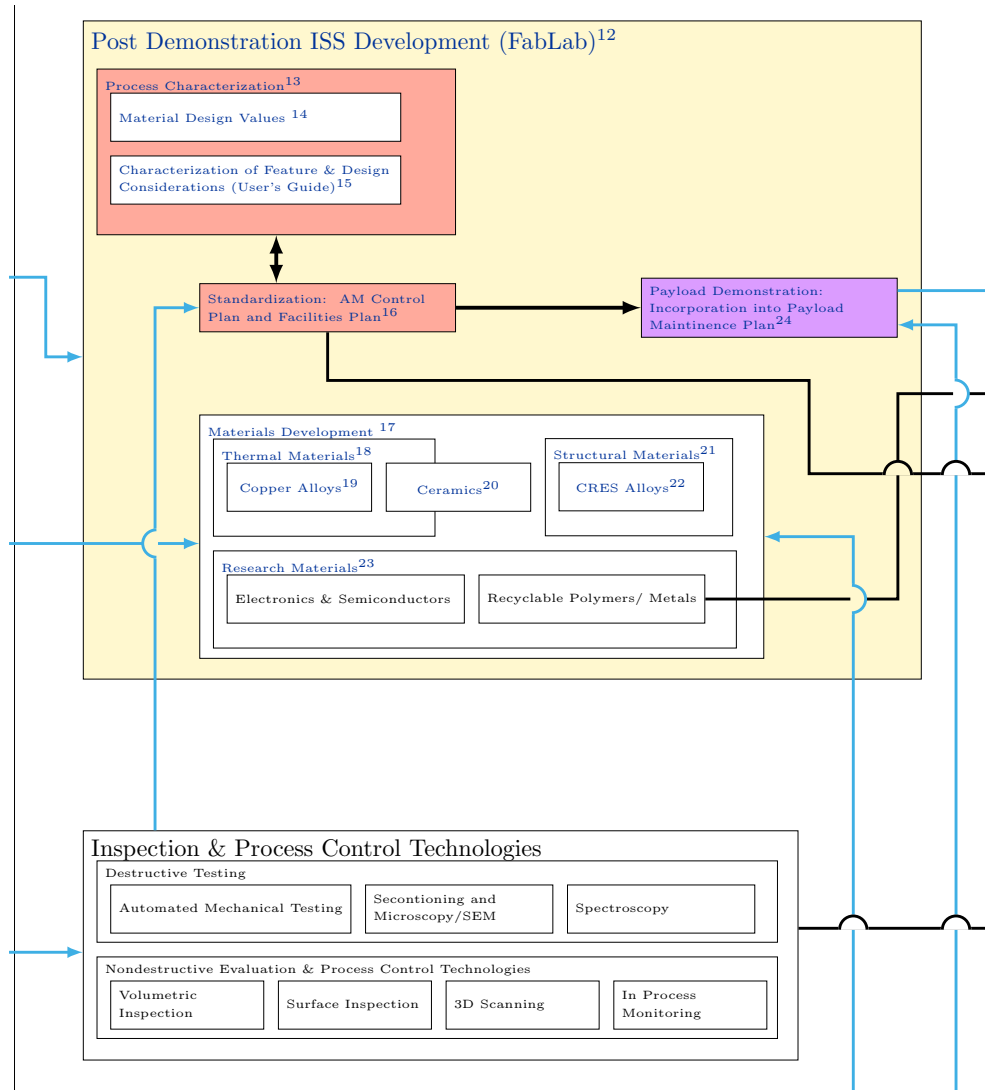
- Act as a pathfinder for processes
- Serve a testbed for materials and tooling

Exit: The demonstration phase culminates in the on-orbit testing of the FabLab payload.

Additional Low TRL activities noted for future infusion



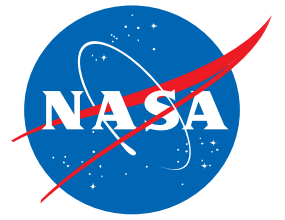
Characterize



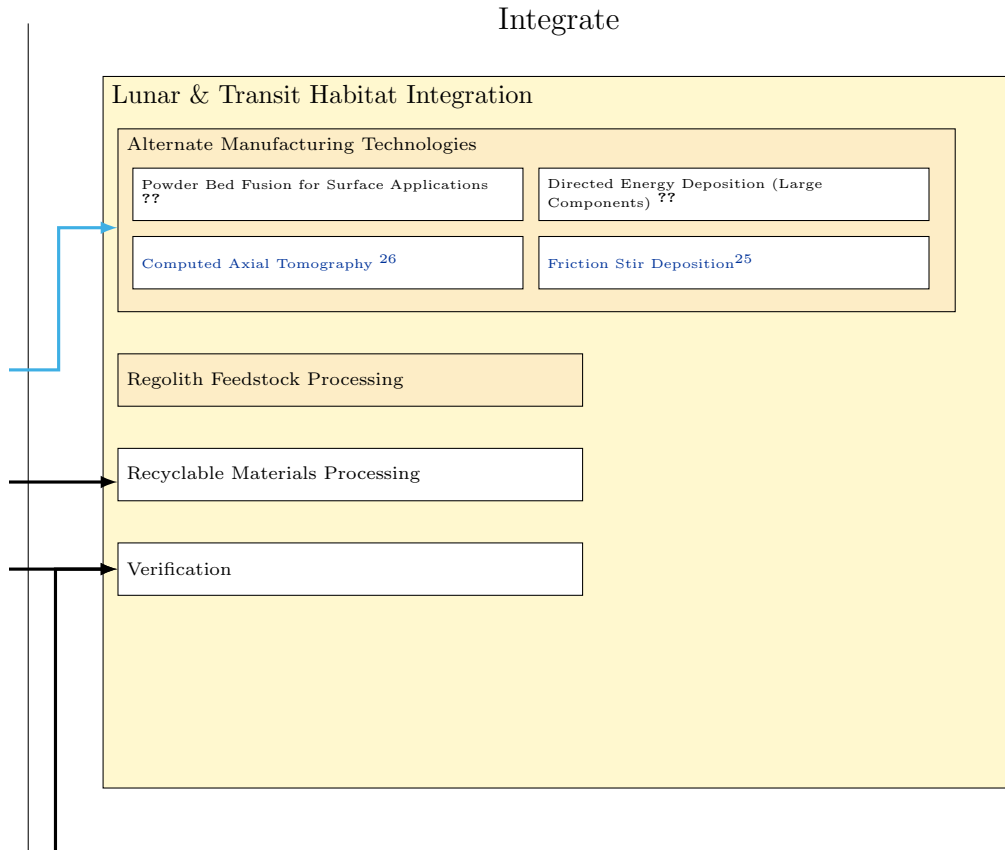
Objective: utilize payload as a pathfinder to develop an approach for use of in space manufacturing technologies

- Emphasis: developing an approach to either meet NASA standards or inform revision of those standards for use in the space environment.
- Secondary Objective: part verification and inspection.

Exit: baselining an in space manufactured component in the Maintenance or assembly plan for an external payload.



Integrate



Objective: transition of technology demonstrators and approaches developed during phase I and II into mission architectures and lunar surface applications.

- development of second-generation hardware with application specific focus
- heavy focus on application specific technologies and advanced feedstocks.

Exit: Project Completion → Development of Additional Manufacturing Technologies