



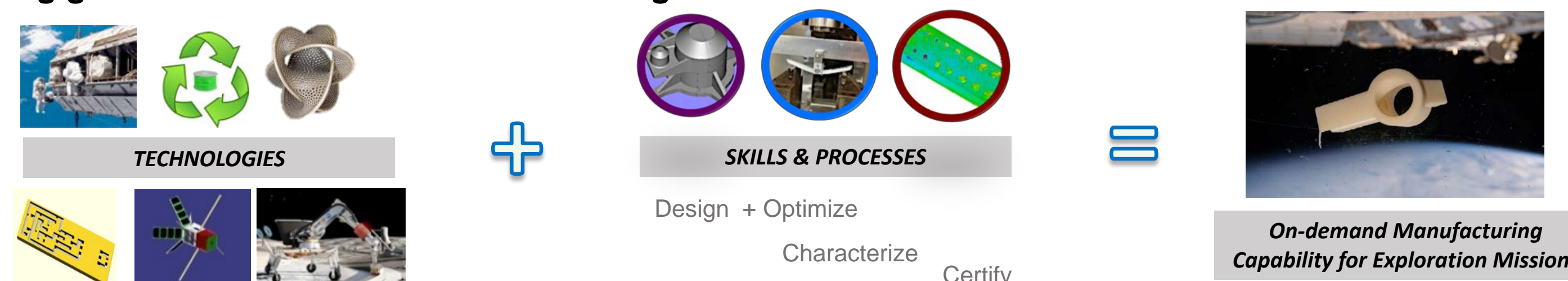
In-Space Manufacturing Project at NASA Marshall Space Flight Center

National Aeronautics and Space Administration



In-Space Manufacturing (ISM) Overview

- Responsible for developing advanced manufacturing capabilities to reduce Earth dependence and enable sustainable manufacturing for long duration exploration missions
- Test & advance desired technologies
- Establish skills & processes (design, characterization, certification) to enable new capabilities to become institutionalized
- Leverage industry, academia, & other government agencies to meet these objectives
- Utilize ground-based and space-based demonstrations
- International Space Station (ISS) proving ground for evolution of new technologies



ISS: The Proving Ground for Space-Based Manufacturing Technologies

3D PRINTING IN ZERO G TECHNOLOGY DEMONSTRATION MISSION

- Payload developed through a phase III Small Business Innovative Research (SBIR) contract with Made In Space
- First demonstration of 3D printing on-orbit
- Manufactured 42 ground control and flight specimens as part of phase I (Nov.-Dec. 2014) and 34 additional flight specimens as part of phase II (June-July 2016)
- Specimens evaluated for density, dimensional variation, internal structure, mechanical properties, and chemical composition
- No engineering significant effects on the Fused Deposition Modeling (FDM) process noted to date



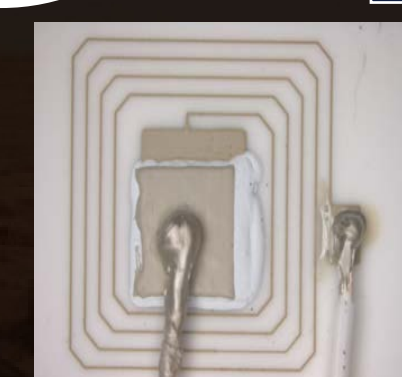
REFABRICATOR: RECYCLING ON-ORBIT AND CLOSING THE MANUFACTURING LOOP

- In-space recycler technology demonstration for the International Space Station (ISS)
- Unit is an integrated printer and recycler to demonstrate the feasibility of plastic recycling in a zero gravity environment
- Payload Developed by Tethers Unlimited Inc. (TUI) under a Small Business Innovative Research (SBIR) contract
- ReFabricator implements a technique called Positrusion (developed by TUI) for producing high quality feedstock from input plastic material
- Ability to process onboard waste plastic materials into useful feedstock for further use could translate into launch mass savings for future crewed missions
- Technology also has broader significant to reprocessing of plastic materials on earth
- Payload will be operational on ISS in 2018



Ground Based Research and Development Activities

- Development of printed, infusible technologies for sensing, energy harvesting, and energy storage using the nScript capability for printable electronics
- Ground-based studies on manufacturing process optimization for fused deposition modeling
- Microstructural material modeling of fused deposition modeling with group at Ames Research Center (ARC)
- Project on making filament and 3D printing with biologically derived materials (collaboration between Kennedy Space Center VEGGIE experiment, Ames Research Center Synthetic Biology Group, and ISM project at MSFC)



Printed wireless humidity sensor



Plant growth in 3D printed blocks of biologically derived filament

Toward a Multimaterial Fabrication Facility for ISS ("FabLab")

- Utilization of Made in Space's Additive Manufacturing Facility (AMF) for materials characterization studies and production of functional parts for ISS use
- Development of constituent FabLab technologies through SBIR opportunities:
 - 3D printing of metals (Techshot)
 - sterilization of 3D printed parts for biomedical applications (Tethers Unlimited)
 - Development of higher strength, thermally reversible thermoset materials for 3D printing (Cornerstone Research Group)
 - development of additive electronics capabilities
 - Hybrid manufacturing capability for precision parts
- Broad agency announcement for MultiMaterial Fabrication Laboratory for ISS in April 2017