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- **Title:** 3D Printing In Zero-G ISS Technology Demonstration
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**Abstract:**

The National Aeronautics and Space Administration (NASA) has a long term strategy to fabricate components and equipment on-demand for manned missions to the Moon, Mars, and beyond. To support this strategy, NASA and Made in Space, Inc. are developing the 3D Printing In Zero-G payload as a Technology Demonstration for the International Space Station (ISS). The 3D Printing In Zero-G experiment ('3D Print') will be the first machine to perform 3D printing in space.

The greater the distance from Earth and the longer the mission duration, the more difficult resupply becomes; this requires a change from the current spares, maintenance, repair, and hardware design model that has been used on the International Space Station (ISS) up until now. Given the extension of the ISS Program, which will inevitably result in replacement parts being required, the ISS is an ideal platform to begin changing the current model for resupply

and repair to one that is more suitable for all exploration missions.

3D Printing, more formally known as Additive Manufacturing, is the method of building parts/objects/tools layer-by-layer. The 3D Print experiment will use extrusion-based additive manufacturing, which involves building an object out of plastic deposited by a wire-feed via an extruder head. Parts can be printed from data files loaded on the device at launch, as well as additional files uplinked to the device while on-orbit. The plastic extrusion additive manufacturing process is a low-energy, low-mass solution to many common needs on board the ISS. The 3D Print payload will serve as the ideal first step to proving that process in space.

It is unreasonable to expect NASA to launch large blocks of material from which parts or tools can be traditionally machined, and even more unreasonable to fly up multiple drill bits that would be required to machine parts from aerospace-grade materials such as titanium 6-4 alloy and Inconel. The technology to produce parts on demand, in space, offers unique design options that are not possible through traditional manufacturing methods while offering cost-effective, high-precision, low-unit on-demand manufacturing. Thus, Additive Manufacturing capabilities are the foundation of an advanced manufacturing in space roadmap.

Cases for using Additive Manufacturing on-orbit include:

- Known/Predicted Repair: limit need for 'stockpiling' of parts
- Known Production & Assembly: Structural and geometrical constraints caused by launch loads and vehicle stowage requirements may be by-passed in order to build components in space and taking advantage of the absence of gravity.
- Unknown Repair & Replacement: The ability to create makeshift replacement tools while waiting for resupply could prevent flight experiments from losing critical run-time as well as possibly serving as a life saver in critical human systems equipment.
- New Experimentation Advantages: Given the opportunity to build freeform shapes in space, researchers on the ground and on-board alike will undoubtedly discover new and interesting ways to use the technology. One such opportunity is to include educational aspects where students can design and build parts in space. The applications opportunities become virtually boundless.

The 3D Printing In Zero-G experiment will demonstrate the capability of utilizing Additive Manufacturing technology in space. This will serve as the enabling first step to realizing an additive manufacturing, print-on-demand "machine shop" for long-duration missions and sustaining human exploration of other planets, where there is extremely limited ability and availability of Earth-based logistics support.

The 3D Printing In Zero-G on-orbit goals and objectives include:

1. Successfully perform extrusion-based additive manufacturing on-orbit by printing multiple parts from ABS Polymer Material
2. Demonstrate nominal extrusion and traversing

3. Perform 'on-demand' print capability via CAD file uplink for requested parts as they are defined
4. Mitigate Functional & Design Risks for Future Facilities
5. Test print volume sizes
6. Replace/Refill Feedstock on-demand
7. Perform STEM Activities

Simply put, Additive Manufacturing in space is a critical enabling technology for NASA. It will provide the capability to produce hardware on-demand, directly lowering cost and decreasing risk by having the exact part or tool needed in the time it takes to print. This capability will also provide the much-needed solution to the cost, volume, and up-mass constraints that prohibit launching everything needed for long-duration or long-distance missions from Earth, including spare parts and replacement systems.

A successful mission for the 3D Printing In Zero-G payload is the first step to demonstrate the capability of printing on orbit. The data gathered and lessons learned from this demonstration will be applied to the next generation of additive manufacturing technology on orbit. It is expected that Additive Manufacturing technology will quickly become a critical part of any mission's infrastructure.