

Additive Manufacturing Facility (AMF) User Guide

MADE INSPACE



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1. Introduction

The Additive Manufacturing Facility (AMF) is a gravity independent 3D plastic printer approved for International Space Station (ISS) operations. Built by Made In Space, Inc., (MIS) the AMF will be used by NASA and the Center for the Advancement of Science in Space (CASIS) as part of the ISS U.S. National Laboratory. The AMF will produce hardware on-demand, in-space for experimentation, tools, parts, education, and microgravity research. Some of the benefits of in-space additive manufacturing are faster delivery time, customization, lighter, more optimized parts, and limited necessary human interaction. Built to be modular and upgradeable, the AMF will also be used as a research platform to advance other in-space manufacturing techniques.

CONTACT Email: info@madeinspace.us / Web: www.madeinspace.us

2. Description of Services

For AMF in-space printing services, customers pay MIS to reserve a 3D print slot and can either provide their own 3D model or commission Made In Space to design one. Payment also covers AMF operational costs:

- ISS IVA Station-Certified Materials
- MIS Transport & Stowage to ISS
- MIS Safety Qualification & Human Factors Implementation Team
- ISS Documentation, Facilitation, Administration

Once a model is fabricated on and removed from AMF, depending on the mission, it can be utilized, stowed, returned to Earth, or even launched into Low Earth Orbit (LEO).

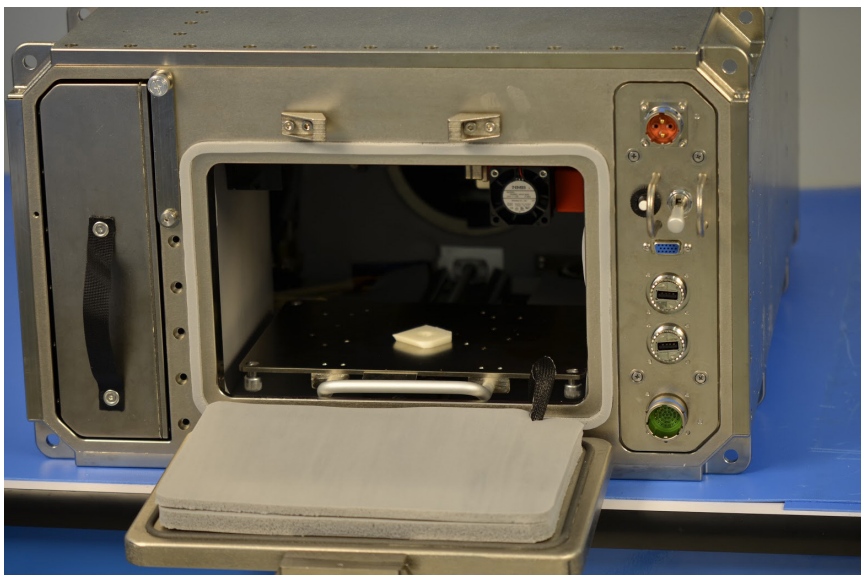
In addition to printing services, the AMF will also be used as a platform to facilitate other research by means of open, public interfaces and modular component design.

3. Technical Description

The AMF has an effective build volume of 14cm x 10cm x 10cm. Initially the AMF will print with ABS, HDPE, and PEI-PC polymers but it is designed to print with other materials as they become approved for ISS operations. The AMF was built to last the remaining lifetime of the space station. It can be operated locally and remotely, including from Earth. The AMF filters both nanoparticles and toxic gases out of the air.



MIS accepts .stl, .stp, .step, .int, .its, .ipt, .igs, .iges and .prt files for 3D models, other CAD file formats are possible but may require editing.



The AMF is designed to be installed into an easily accessible ISS International Standard Payload rack and the interfaces for its modular components are public and open, allowing 3rd party custom hardware upgrades and innovations. Interfaces can be found at: <http://www.sbmspec.com>

4. Facts at a Glance

Printing Capabilities

Print Volume (mm): 140 L x 100 W x 100 H
Material: ABS, HDPE, PEI+PC (more possible upon request)
X/Y Resolution: 0.025 – 0.44 mm; Nominal: 0.15 mm
Z Resolution: Down to 75 micron layer height
Min. Wall Thickness: 1 mm
Threaded holes: >M10

Interfaces

1 Touch Screen Display
2 USB ports
1 VGA port
1 Ethernet port

Power

Input power: 28V DC @ 12A
Power Usage: 600 W

Temperatures

Extruder Temperature: 180 C – 375 C
Heated Print Bed
Heated Volume

Unique Features

Real Time Video and Status Monitoring
Modular Material Extruder, Print Bed, Feedstock Canister, and Filter
Simple, One-Hand replacement of modular components
Material robustness allows for future support of entirely new materials
Utilizes Open, Public Space-Based Manufacturing Specifications (SBM-Spec)

Built to withstand a rocket launch!

Printer Device Details

Dimensions (mm): 566.5 x 460.4 x 273.2
Weight: 45 Kg (on Earth)
Chassis Metal: Machined Aluminum
Current Location: ISS Express Rack
Printing Method: FFF / PJP



MIS AMF Mission Patch

5. Cost

The price of a print slot will vary depending on the requirements and urgency of the print. For a simple, small part with low priority in the queue, the price can be less than \$9,000. For a high priority print with multiple parts, high complexity, and/or parts that require Made In Space Engineering time, costs could be one or two orders of magnitude higher.

6. How To Use / Timeline

Below is a general outline of the steps we take to 3D print something on the ISS. The subsequent lengths of time give a general range of the time each step can take.

1. Customer submits print request to MIS and gets quote. 1-2 days.
2. Customer and MIS enter into a Memorandum of Understanding. 1-30 days.
3. MIS receives payment and model as agreed upon in MOU. 1-10 days.
4. MIS assesses and optimizes printability of 3D model for AMF. 1-2 weeks.
5. MIS test prints the object on a flight-like ground AMF. 1-4 weeks.
6. MIS gets NASA Human Factors Implementation Team (HFIT) approval. 2-4 weeks.
7. MIS schedules a print time and crew operation aboard ISS. 1-6 weeks.
8. Object model file is uploaded to the ISS. 1-2 days.
9. Ground control and support for on-orbit printing operations. 1-2 weeks.
10. Post-print activities (remove part from print tray, photography, measurements, storage, etc.)
11. Downmass to Earth and deliver to customer (optional)

MIS understands that every order is unique and may require additional deliverables. Please contact us with questions or idea submissions at the emails provided below.

7. Contact Information

For general information, please contact: info@madeinspace.us

For media and press inquiries, please contact: media@madeinspace.us

To utilize AMF for on-orbit operations, please contact: business@madeinspace.us
or fill out the form found here: <http://www.madeinspace.us/projects/amf/>

Made In Space, Inc. 153 Dailey Rd. Mountain View, CA 94035

8. Promotion

All public references to MIS, CASIS, NASA, AMF, Lowe's, as well as any other project details must be approved by MIS. All promotional material is subject to guidelines and rules established by the United States Government, MIS, and their partners.

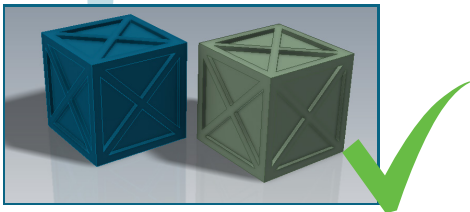
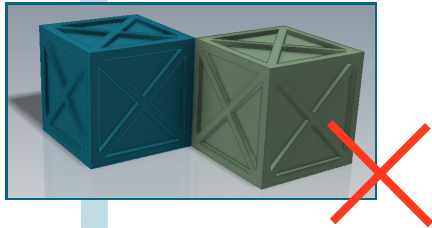
9. Confidentiality

Made In Space will sign a Non-Disclosure Agreement (NDA) with customers and business partners who request it. All designs submitted to Made In Space are kept confidential by default.

10. Design Guide

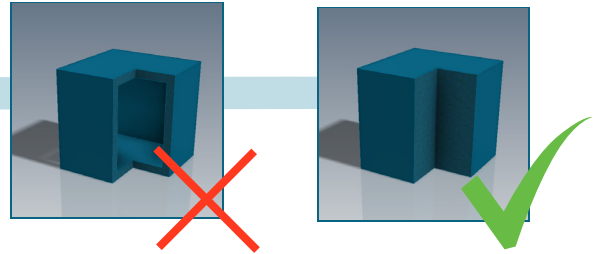
SPACING

Ensure that you have at least 1 mm of separation between parts that are meant to be separate



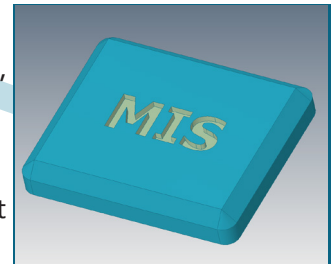
SOLID

Your model should be solid geometry for 3D printability, walls should have a thickness of at least 1 mm.



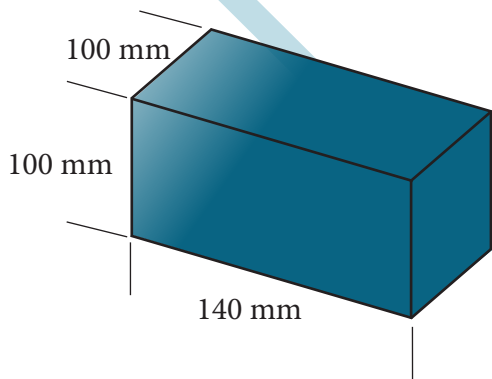
EMBOSSED / ENGRAVED FEATURES

For engraved text or surface details, we recommend letters with a minimum line thickness of 1 mm and a depth of 0.3 mm. For embossed text and surface details, we recommend letters that have a line thickness of at least 2.5 mm and a depth of at least 0.5 mm. Letters should be spaced out by at least 1 mm from each other.



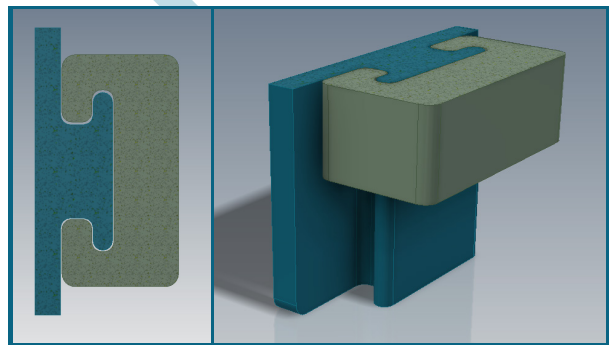
PRINT VOLUME

Your model should fit within a 14 cm long, 10 cm wide, and 10 cm tall box.



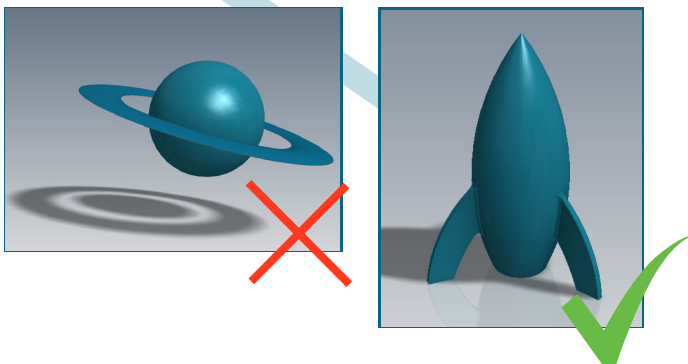
SNAP-FIT

A part that is designed to fit into another part and does not move. Snap fit guidelines are: 0.2mm on every side. (0.4mm diameter difference if an axle)



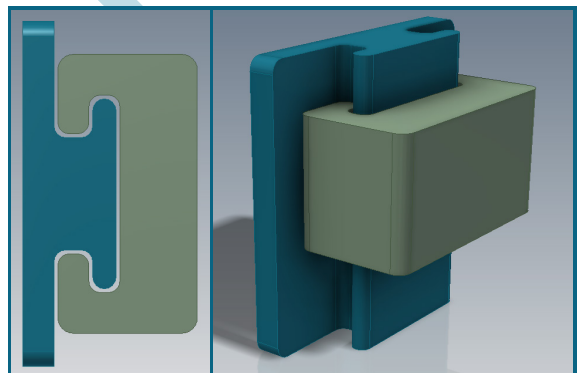
SUPPORT STRUCTURE

Support structure is not available. Only supported geometries, with at least 45° angled supports are guaranteed to print.



SLIP-FIT

A part that is designed to rotate or slide within another part. Slip fit guidelines are: 0.5mm on every side. (1 mm diameter difference if an axle)



11. Tools & Parts

With the AMF, the tools and parts can be custom made according to individual user preference and application specific needs.

Additionally, when unforeseen events occur, custom tools or unique geometries can

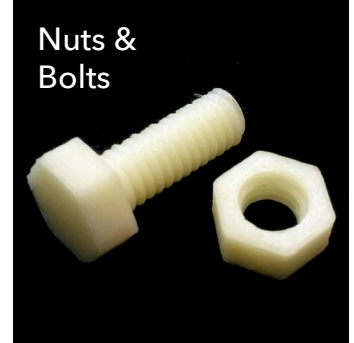
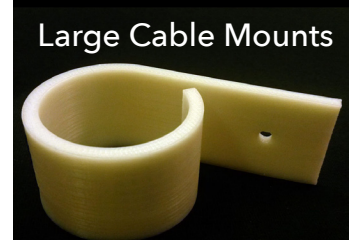
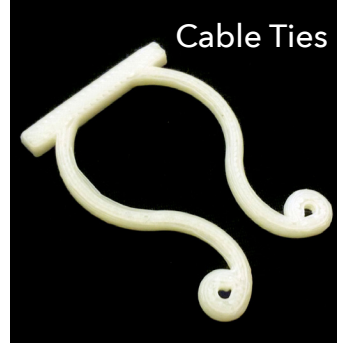
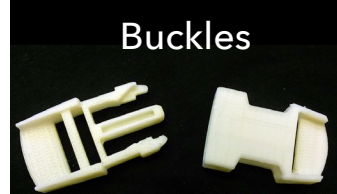
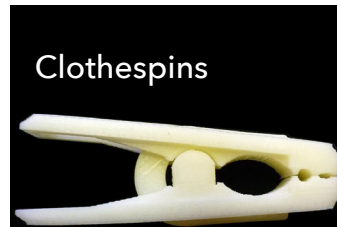
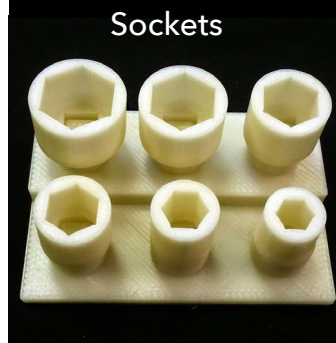
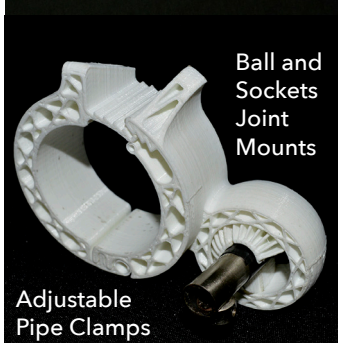
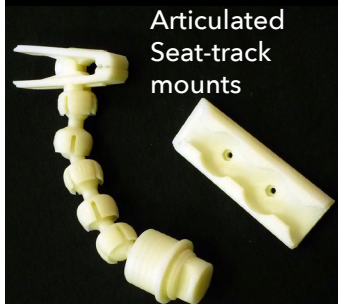
be designed and created on-demand.

As the AMF becomes more and more relied upon, redundant, 3D printable, spare parts can be obviated from ISS operation, providing more

space aboard the ISS for habitation and science.

The AMF provides a faster, cheaper, and safer way to get hardware to space. The full extent to which this technology will transform life in space is not yet known, but below are some ideas MIS has had.

Examples



12. Research

The ability to build objects in space while avoiding the rigors of launch opens up entirely new opportunities for research in space.

Components that could not even survive their own weight on Earth, let alone a ride

on a rocket, can now be the focus of new and unique research.

Techniques which require the repetitive use of disposables like sample containers, pipette tips, tube clamps, valves, etc. no longer have to be delayed

indefinitely when those disposables run out, go missing, or break.

Below are some ways in which MIS thinks the AMF can be helpful for both traditional research as well as new opportunities for science.

Examples



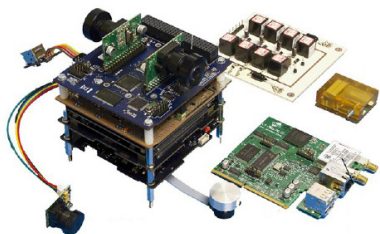
13. Stash & Deploy

Through a partnership with Nanoracks, Made In Space will use the AMF to print satellite structure. NanoRacks will supply satellite components, enabling on-demand satellite deployment capabilities.

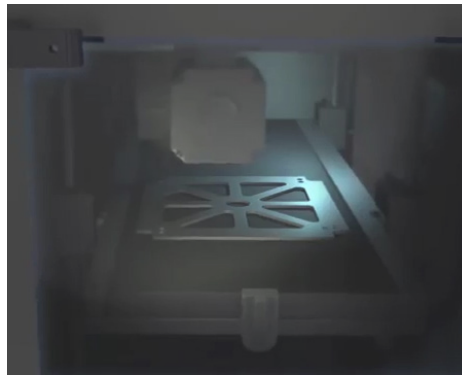
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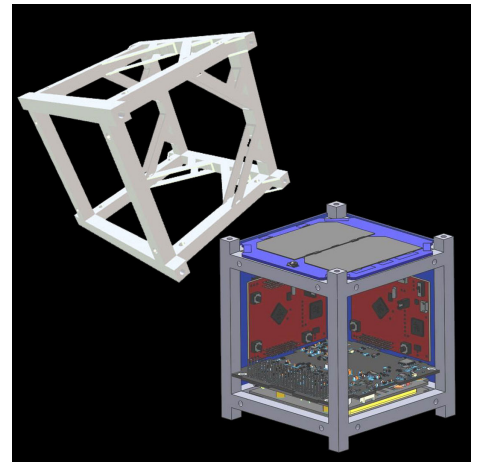
1 NanoRacks launches modular CubeSat components to ISS. Satellite developers on Earth can use this inventory of “stashed” components for their CubeSat designs.



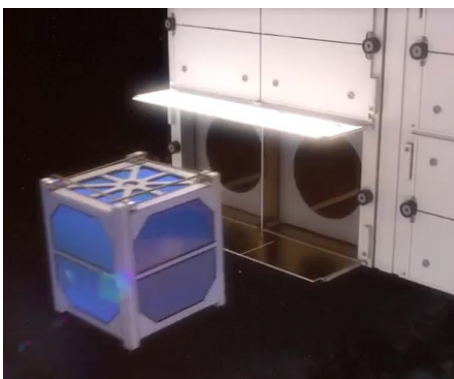
2 Once a CubeSat design is finalized, an optimized CubeSat structure will be 3D printed on station.



3 The printed structure for that CubeSat is then integrated with the pre-selected stashed components.



4 The resulting integrated and assembled CubeSat is then launched into space by NanoRacks.



5 The partially 3D printed CubeSat enters into Low Earth Orbit along a trajectory that avoids any possible collision with the ISS.



6 When the CubeSat reaches a safe distance from the ISS, the power systems are turned on and the Satellite begins operation.

