“Can you really do anything with plastics?”
NASA Advanced Manufacturing Technology
For In-Space Applications

Tech Demos, Testing, Science Processes,
ISS-based

Exploration, Sustainment, In-Situ Resources

Planetary Surfaces

Technology Development
Earth-based

Deep Space Missions
The 3D Print project will deliver the **first 3D printer** on the ISS and will investigate the effects of **consistent microgravity** on fused filament additive manufacturing by printing parts in space.

### Potential Mission Accessories
- Threads
- Springs
- Buckles
- Caps
- Clamps

### 3D Print Specifications
- **Dimensions**: 33 cm x 30 cm x 36 cm
- **Print Volume**: 6 cm x 12 cm x 6 cm
- **Mass**: 20 kg (w/out packing material or spares)
- **Est. Accuracy**: 95%
- **Resolution**: .35 mm
- **Maximum Power**: 176W (draw from MSG)
- **Software**: MIS SliceR
- **Traverse**: Linear Guide Rail
- **Feedstock**: ABS Plastic

Fused Filament Fabrication: 1) nozzle ejecting molten plastic, 2) deposited material (modeled part), 3) controlled movable table.
### Experience and Partnerships

#### Earth-Based

**Pre-2014**

|------|------|------|------|------|------|---------|------|---------|

Fused Filament Fabrication (FFF) at Marshall Space Flight Center

- Procured FFF system, 1993
- Expanded operational temperature range
- More materials as filaments
- KC-135 flights, 1999

* Total flight time: 10 – 12 Hours
* Total operational time: 1 hour 20 minutes

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**NASA's Partnership with Made In Space, Inc**

- KC-135 flights through NASA's Flight Opportunities Program, Summer 2011

  - Awarded SBIR Phase 1, December 2011
    * Goal: Design AM system for ISS
  - Technical Interchange w/ MSFC, Fall 2012
  - Awarded SBIR Phase 2 and Phase 3, Early 2013
    * Goal: Provide flight-certificate hardware
Test Early to Reduce Risk

Earth-Based

Pre-2014

Risk Mitigation Testing,
Summer 2013

- Functional Print Tests
- Fit Checks in MSG
- Electromagnetic Interference/
  Compatibility Testing
- Vibration Testing

Made In Space, Inc. worked with subject matter experts at NASA to identify potential risks before critical design review (CDR) to meet an aggressive schedule and budget with minimal margin.
Set-Up and Operations

ISS Tech Demonstration


CAD model of the 3D Print printer and electronics box in the MSG

3D Print Flight Unit within the MSG Engineering Unit at MSFC

3D Print Flight Unit with the MSG Engineering Unit in the background
Payload Integration of Flight-Certified Hardware

ISS Tech Demonstration

Flight-Certification Testing

Summer 2014

- Functional Print Tests
- Operation within MSG
- Electromagnetic Interference/ Compatibility Testing
- Vibration Testing
- Noise Emissions

The Flight Unit and Back-Up Flight Unit were successfully delivered to MSFC. The Flight Unit was shipped to JSC June 2014 for payload integration. The Back-Up Flight Unit is located at MSFC.
We Are Ready To Fly!

ISS Tech Demonstration

- Pre-2014
- 2014
- 2015
- 2016
- 2017
- 2018
- 2020-25
- 2025
- 2030 - 40

Hardware is scheduled to be delivered by SpaceX CRS4/ Dragon during the fall of 2014.
“Can you really do anything with plastics?”
Replaceable vs Non-replaceable Parts Currently On-Board ISS

Approximately 28.6% of replace/repair parts are composites and plastics. (Problem Resolution and Corresponding Action database)
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<tr>
<th>Known and Predicted Repair</th>
<th>Unknown Repair &amp; Replacement</th>
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<td>- Wear and tear with use and time</td>
<td>- Create replacement parts</td>
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<td>- Preventive maintenance</td>
<td>- Avoid resupply time</td>
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<td>- Avoid stockpiling geometrically invasive parts</td>
<td>- Potential life-saver in critical human systems equipment</td>
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<th>Known Production and Assembly</th>
<th>New Experimentation Advantages</th>
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<td>- Build components in-space</td>
<td>- Ability to build freeform structures in a 0-G enviro</td>
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<td>- Avoid launch loads</td>
<td>- Driven by on-orbit crew and earth-based scientist needs</td>
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<td>- Avoid stowage requirements</td>
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<tr>
<td>- Take advantage of 0-G enviro</td>
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1. Perform extrusion-based additive manufacturing with ABS filament material on-board the ISS
2. Demonstrate nominal extrusion and traversing activities
3. Perform ‘on-demand’ print capability via computer-aided drawing (CAD) file uplink for requested parts as defined
4. Mitigate functional risks and design risks for future facilities and technology advancements
5. Test print volume scalability
6. Replace and refill filament material (i.e. feedstock) on-demand
7. Perform science, technology, engineering, and mathematics (STEM) outreach activities
**Near-Term Capabilities and Advancements**

### ISS Demonstrations and Earth-Based Activities

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Larger, more capable Advanced Manufacturing Facility  
Structured Light 3D Scanner  
In-Space Recycler  
Metal Survey and Demonstration  
In-Space Materials Database  
Utilization Trade Study and Catalog  
Print-A-Sat / SmallSat  
Printable Electronics
Changing Spacecraft Design

ISS Demonstrations and Earth-Based Activities


Function:
What do we want to happen?

Requirements:
Measurable aspects of the function

Validation:
Did we do what we wanted?

Verification:
Analysis, test, demonstration, inspection

A new way to think of spacecraft design, V&V, and utilization.
Asteroids, Lunar, Mars, and More

Exploration

Asteroids

With more autonomy, understanding of future materials and fabrication processes, the development of new technologies that use in situ resources, FabLabs beyond ISS will advance human exploration into deep-space.
“What will we build?
We will build EVERYTHING”

– Astronaut Don Pettit

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