
3D Printing On The
International Space Station
Tech Demo
"Can you really do anything with plastics?"
3D PRINTING IN ZERO-G EXPERIMENT
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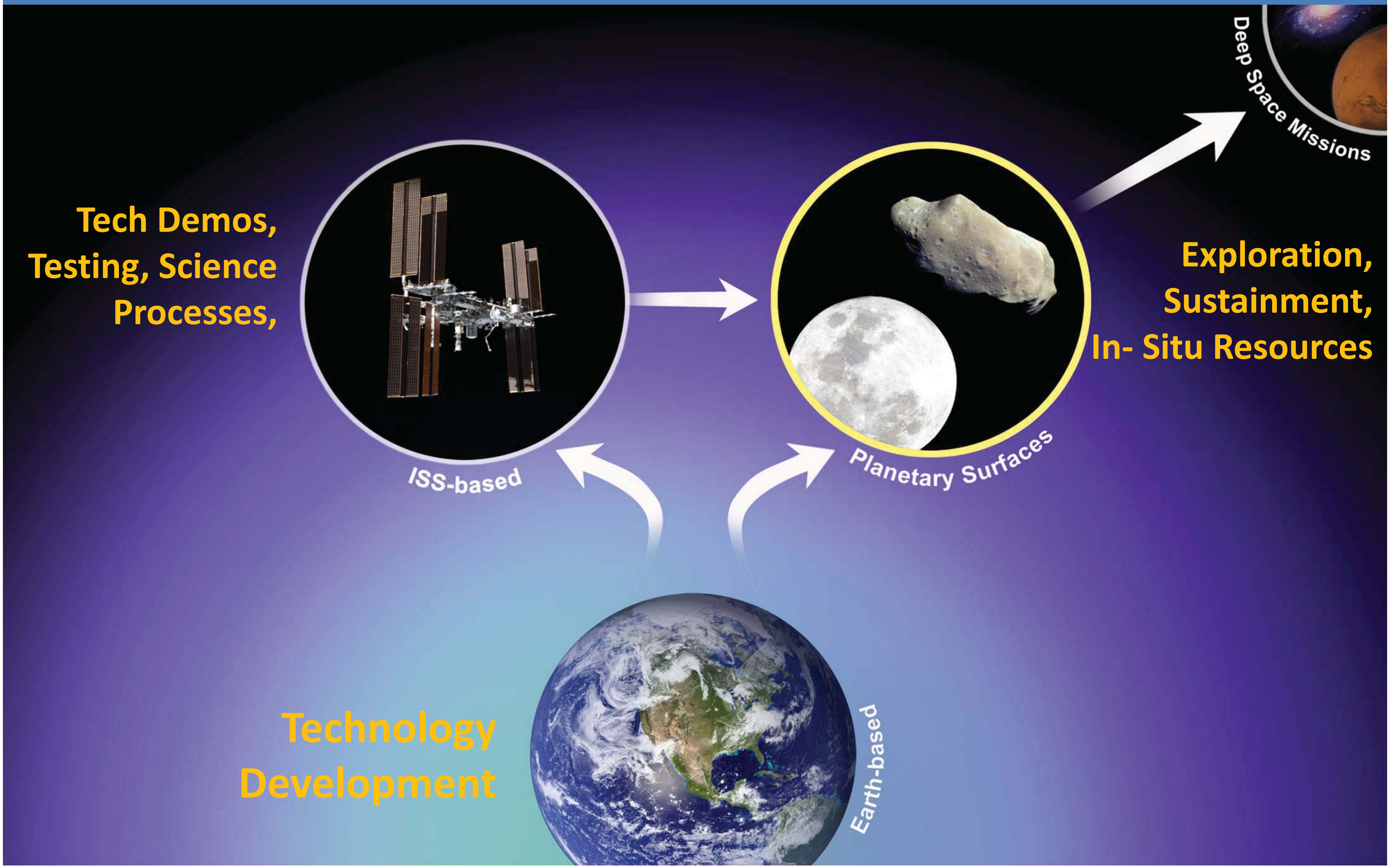
NASA Advanced Manufacturing Technology For In-Space Applications

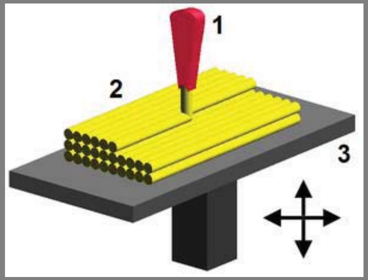


The First 3D Printer On The ISS

Project Overview

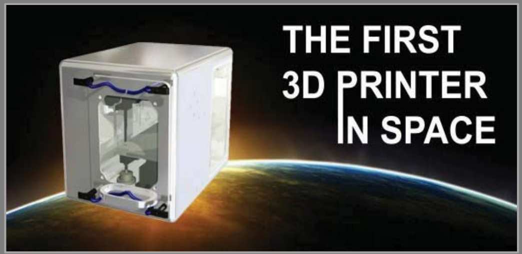
Pre-2014 2014 2015 2016 2017 2018 2020-25 2025 2030 - 40

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**.



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

3D Print in Micro-G Science Glovebox (MSG)



Potential Mission Accessories

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

Experience and Partnerships

Earth-Based

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

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

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- certified hardware

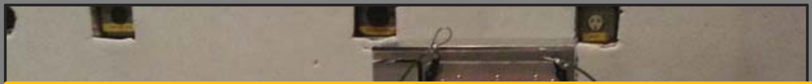
Test Early to Reduce Risk

Earth-Based

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

Risk Mitigation Testing, Summer 2013

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

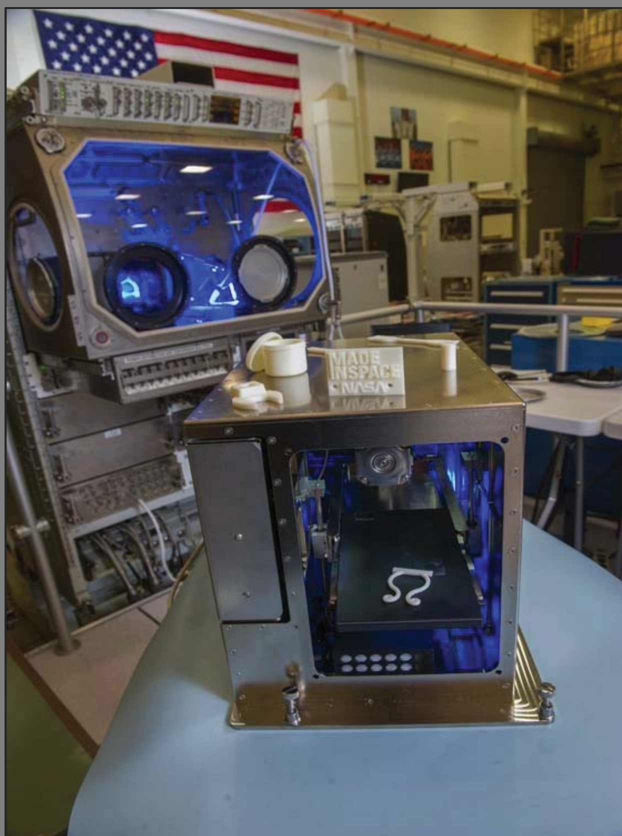


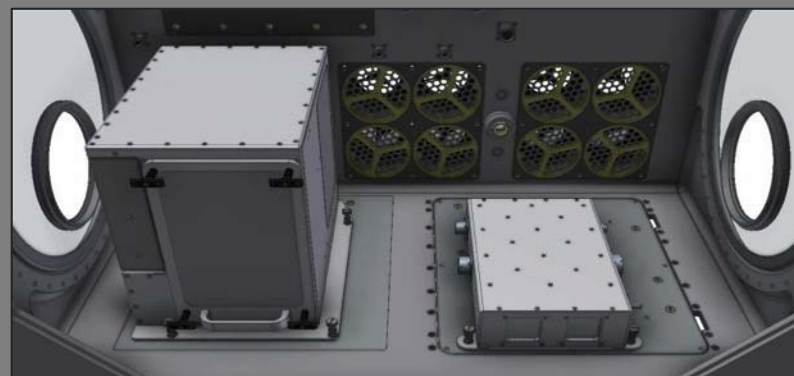
Made In Space, Inc. worked with subject matter experts at NASA to identify potential risks before critical design review (CDR) to meet an *aggressive schedule* and *budget* with *minimal margin*.

Set-Up and Operations

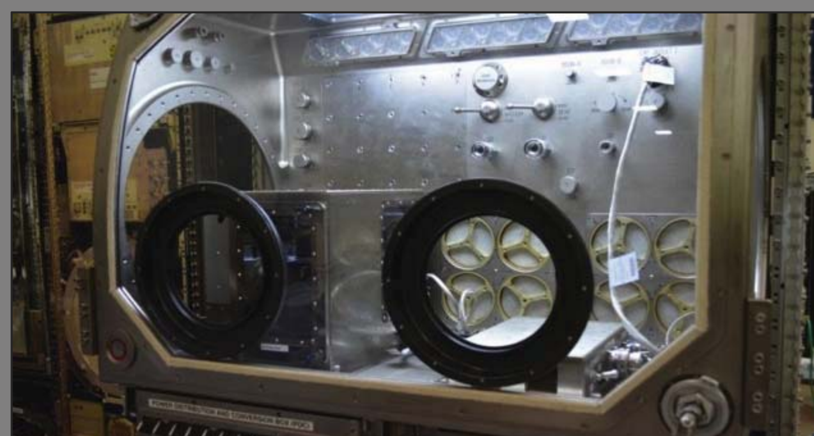
ISS Tech Demonstration

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





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

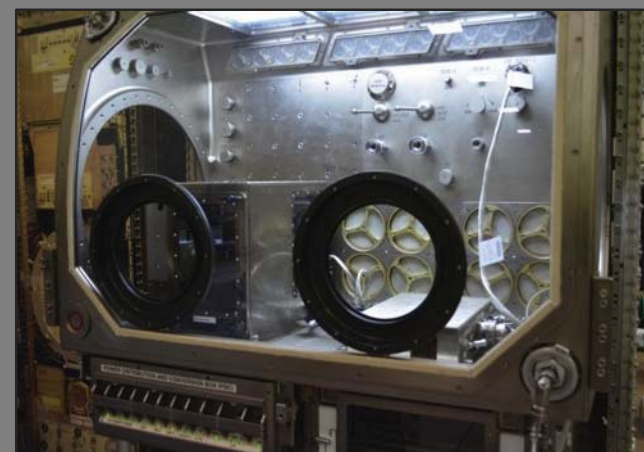
ISS Tech Demonstration

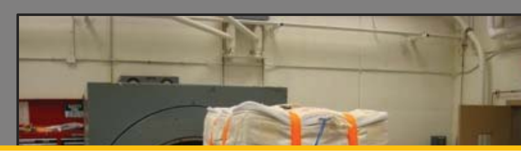
Pre-2014	2014	2015	2016	2017	2018	2020-25	2025	2030 - 40

Flight-Certification Testing

Summer 2014

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



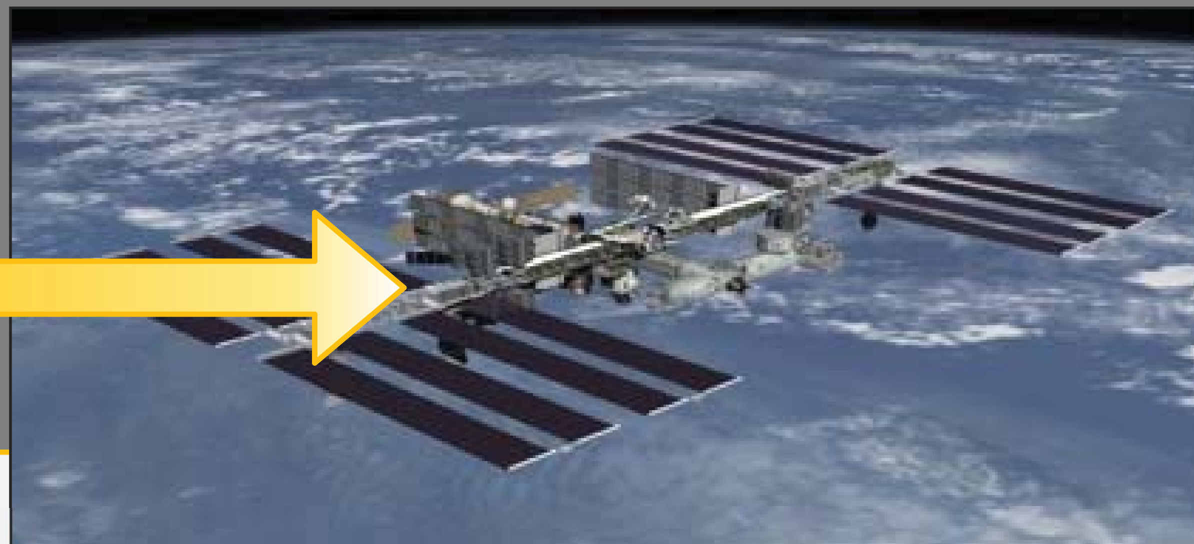


The Flight Unit and Back-Up Flight Unit were successfully delivered to MSFC. The Flight Unit was shipped to JSC June 2014 for payload integration. The Back-Up Flight Unit is located at MSFC.

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.

Capabilities Enabled to Provide On Orbit Solutions

ISS Tech Demonstration

Pre-2014	2014	2015	2016	2017	2018	2020-25	025	2030 - 4

"Can you really do anything with plastics?"

Obvious Solutions for Obvious Problems

ISS Tech Demonstration

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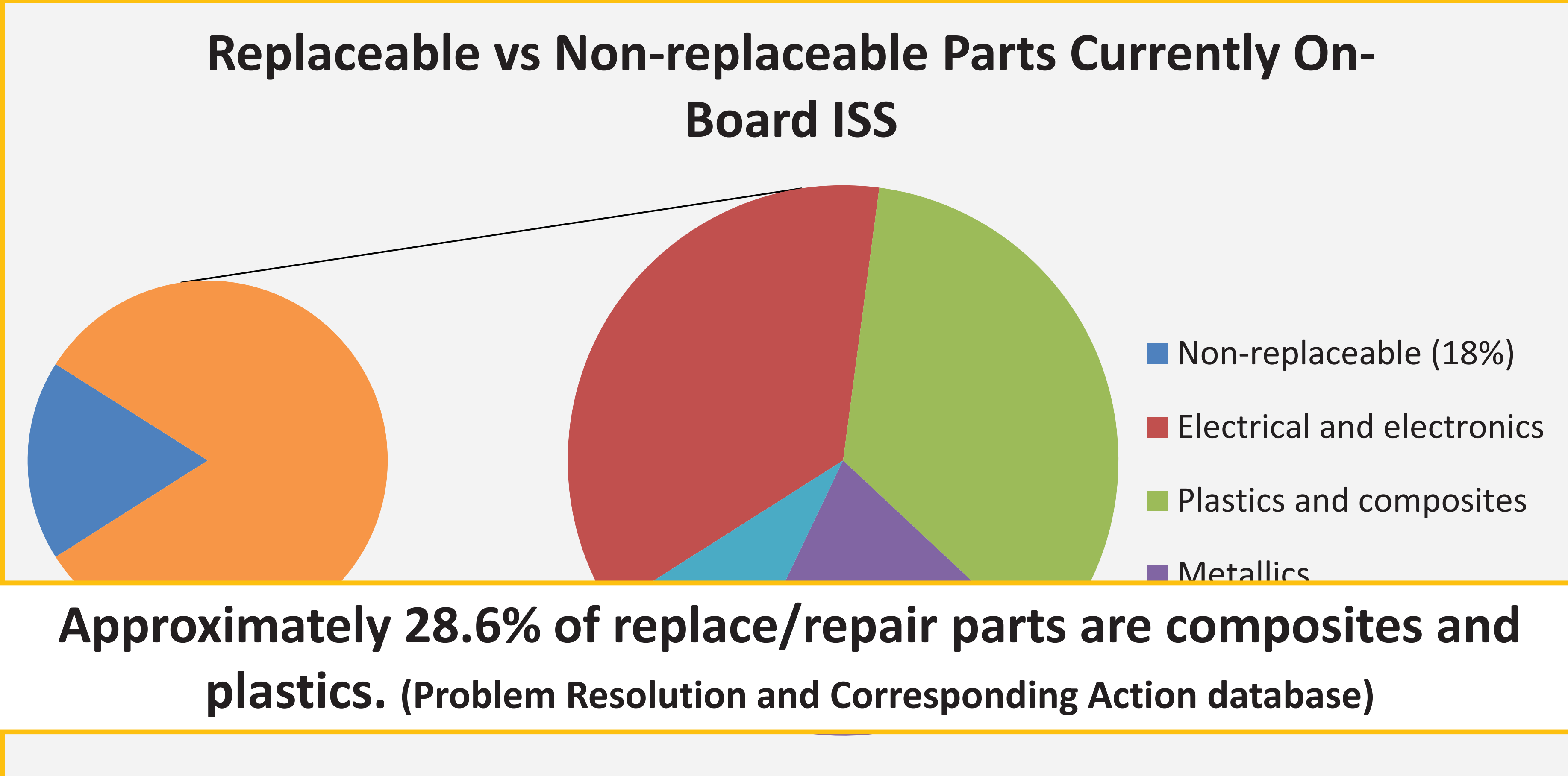


Approximately 28.6% of replace/repair parts are composites and plastics. (Problem Resolution and Corresponding Action database)

Cases for Applying 3D Printing In Space

ISS Tech Demonstration

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

Known and Predicted Repair

- Wear and tear with use and time
- Preventive maintenance
- Avoid stockpiling geometrically invasive parts

Unknown Repair & Replacement

- Create replacement parts
- Avoid resupply time
- Potential life-saver in critical human systems equipment

Known Production and Assembly

- Build components in-space
- Avoid launch loads
- Avoid stowage requirements
- Take advantage of 0-G enviro

New Experimentation Advantages

- Ability to build freeform structures in a 0-G enviro
- Driven by on-orbit crew and earth-based scientist needs

Goals of 3D Printing in Zero-G ISS Tech Demo

ISS Tech Demonstration

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

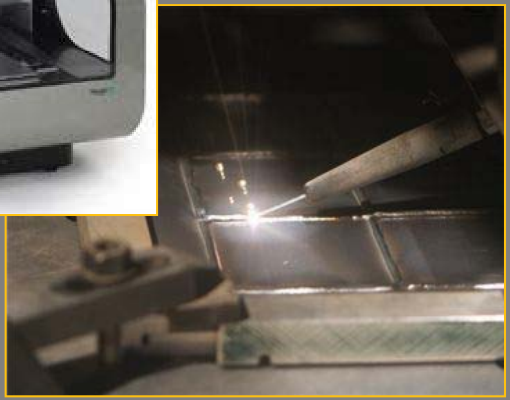
1. Perform extrusion-based additive manufacturing with ABS filament material on-board the ISS
2. Demonstrate nominal extrusion and traversing activities
3. Perform 'on-demand' print capability via computer-aided drawing (CAD) file uplink for requested parts as defined
4. Mitigate functional risks and 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

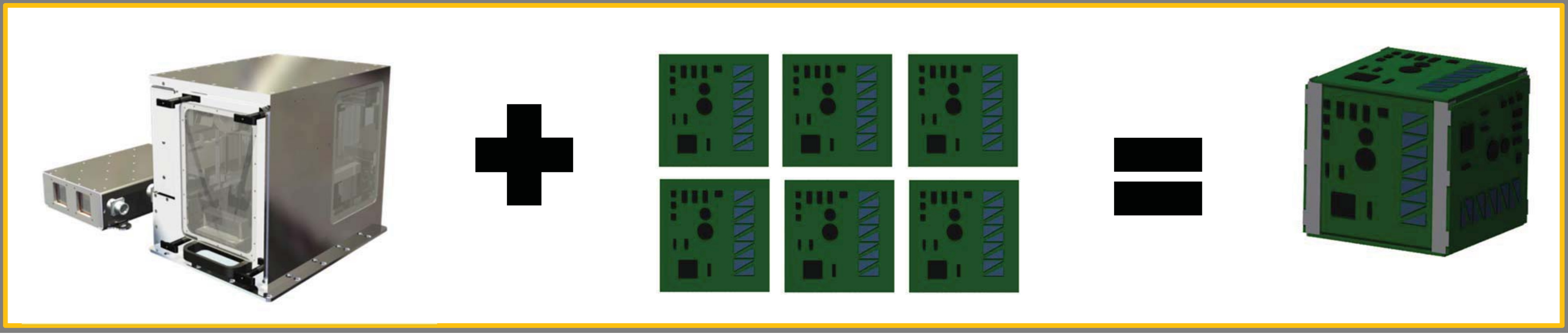
Near-Term Capabilities and Advancements

ISS Demonstrations and Earth-Based Activities

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

- 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





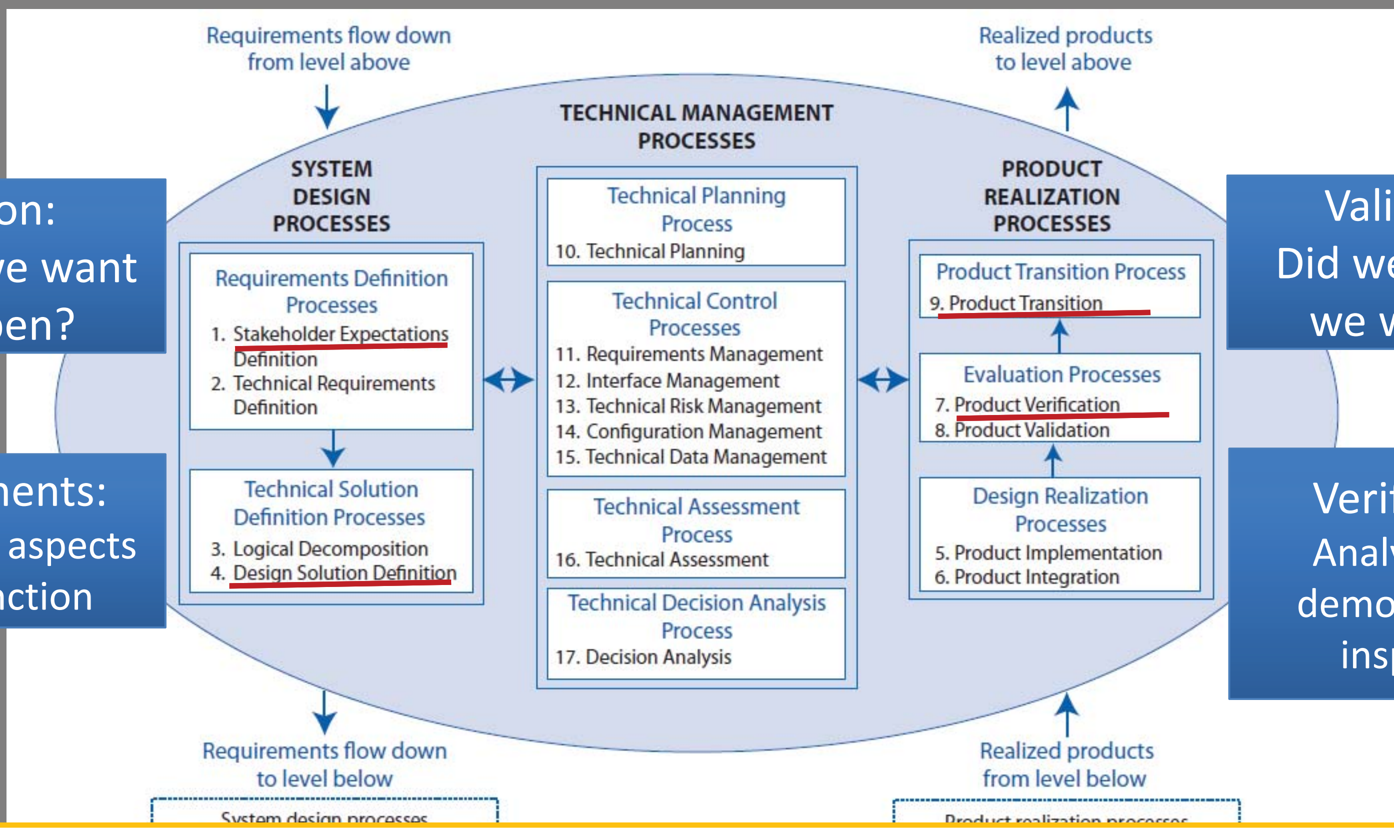
Changing Spacecraft Design

ISS Demonstrations and Earth-Based Activities

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

Function: What do we want to happen?

Requirements: Measurable aspects of the function



Validation: Did we do what we wanted?

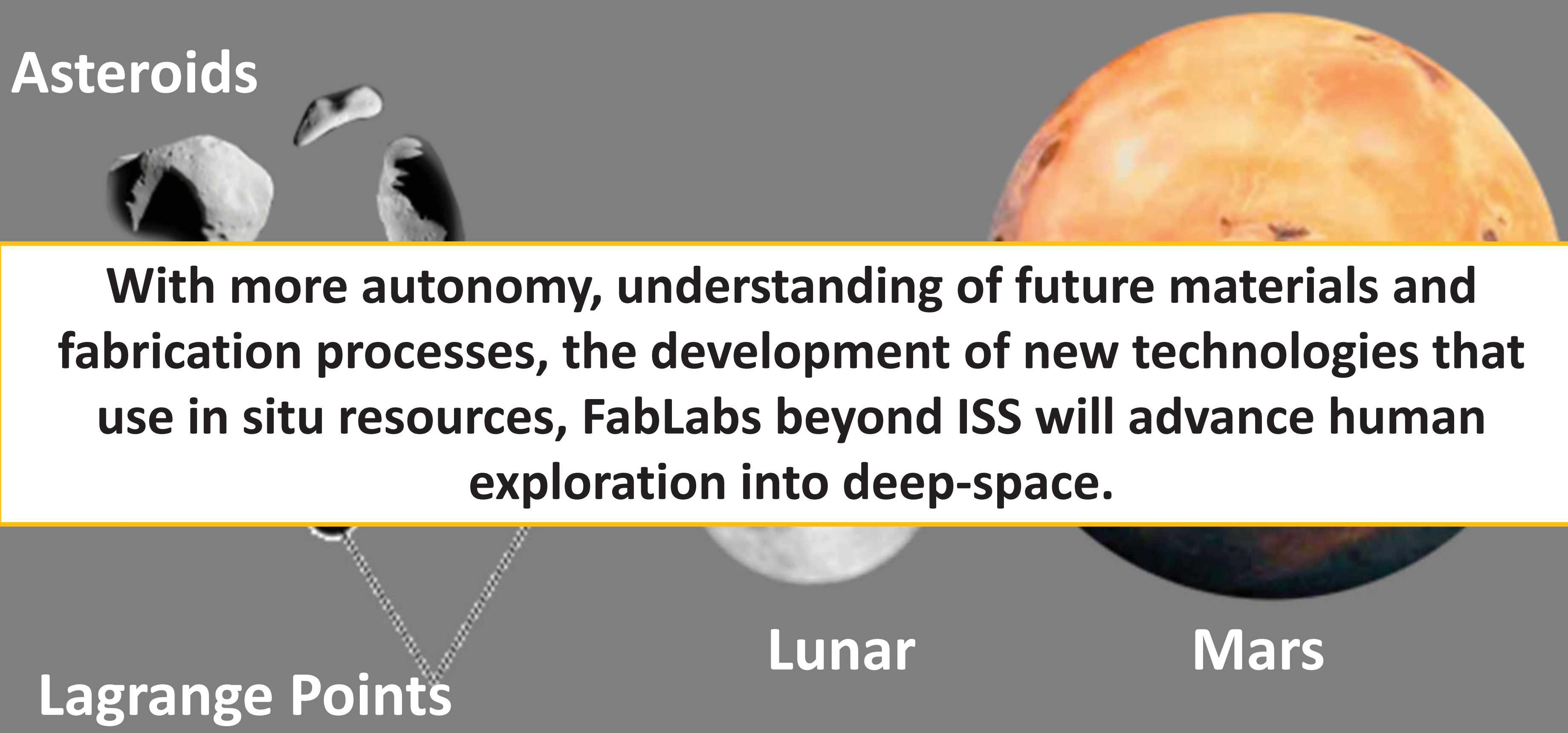
Verification: Analysis, test, demonstration, inspection

A new way to think of spacecraft design, V&V, and utilization.

Asteroids, Lunar, Mars, and More

Exploration

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



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.


NASA
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"What will we build?
We will build EVERYTHING"
– Astronaut Don Pettit