

In-Space Manufacturing (ISM) ISS Refabricator Technology Demonstration

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***Recycling and Sustainable Acquisition (RSA)
Workshop
May 07, 2019***

In-Space Manufacturing (ISM) Project... Make it, Don't Take it!



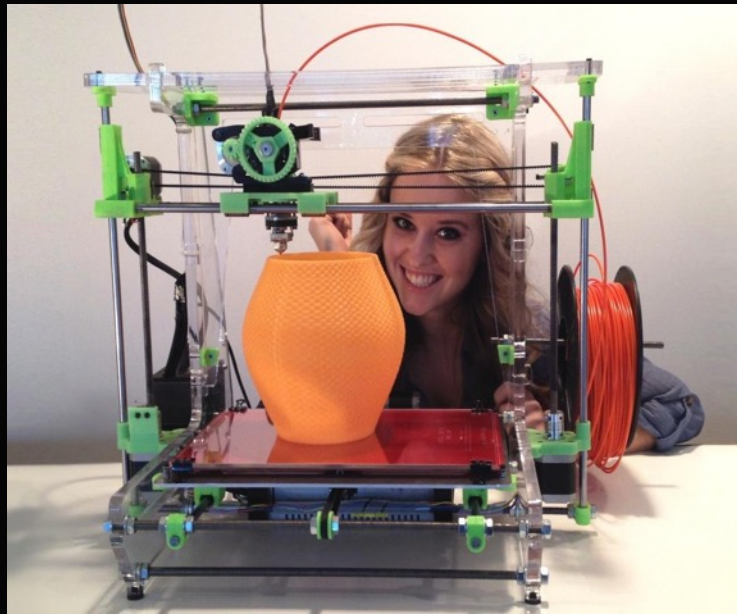
Objective:

To develop and demonstrate on-demand manufacturing, recycling, and repair capabilities for long-duration spaceflight missions.

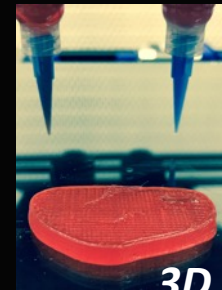
- Replacement parts, repairs, new components from metals, plastics, electronics, and in-situ materials
- Recycling and reuse of waste materials & consumables

What is 3D Printing?

A 3D Printer works a lot like the printers that print out images on paper in two-dimensions, except a 3D Printer actually “prints” three-dimensional objects by layering melted plastic or metals based on the electronic models (i.e. “instructions”) sent to the machine.



Oak Ridge National Labs 3D Printed Car



3D Printed Food



Prosthetics



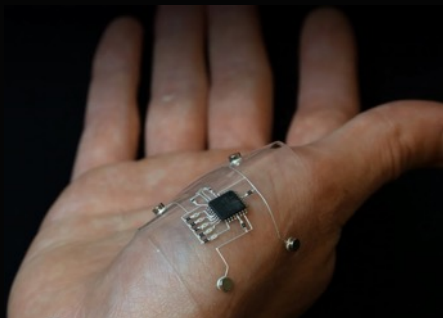
New Balance 3D Printed Shoes



Useful Custom Tools

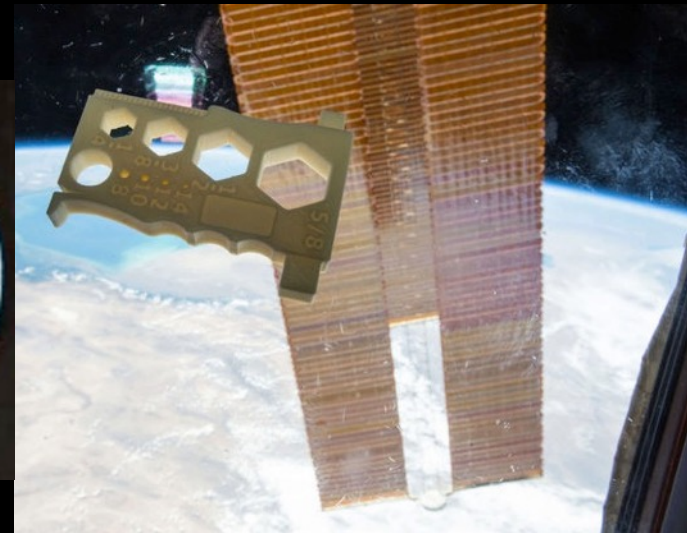
What would YOU
3D Print?

Flexible
Electronics &
Wearables



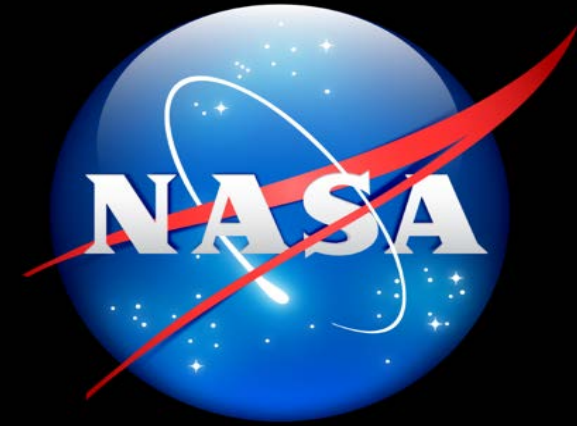
First Step: Does 3D Printing Work in Space?

- In 2014, NASA and the company, Made in Space, Inc. (MIS), sent the first 3D Printer to the International Space Station (ISS) to see if it worked the same in microgravity as it does on Earth.***
- 55 parts were printed on the ISS and then returned to Earth where scientists and engineers at NASA tested and analyzed them to compare them to ground samples.***
- It was determined that plastic parts can be 3D printed in space the same way that they are printed on Earth.***



Why does NASA need 3D Printing?

- *When we live on the Moon or Mars, we will be much farther from Earth than we are on the ISS. Our astronauts won't always be able to wait for a launch to replace consumables, perform maintenance, or fix a broken part.*
- *Remember, the ISS is ~250 miles from Earth, and it only takes a few hours to launch there.*
- *The moon is ~240,000 miles away, and it takes around 3-4 days to get there from Earth.*
- *Mars is ~140 MILLION miles away from Earth (the closest recorded approach in history was 34.8 million miles), and it will take several months to get there.*



Current ISS Resupply Model...



One-of-a-kind Test-bed: The International Space Station (ISS)



NASA “emailed” the first 3D Printed Wrench to space!



1. Design Part



2. Uplink to ISS



4. Make it on ISS



Captain “Butch” Wilmore holding the first 3D Printed Wrench in Space on the ISS. The design file for the wrench was “emailed” (i.e. uplinked) from the ground to the ISS.

And then...the Additive Manufacturing Facility (AMF) by Made in Space, Inc.



- The second 3D Printer, the Additive Manufacturing Facility (AMF), has been operating on the ISS since 2016.
- This printer is owned and operated by Made in Space, Inc. through agreement with the ISS National Lab.
- NASA is one of the customers, as well as other government agencies, industry, and academia.
- The AMF can print with three types of plastic: ABS, ULTEM and High-density Polyethylene (HDPE).

Examples of Parts Manufactured on the ISS AMF



*SPHERES Free Flier Tow Hitch: This part joins two of the ISS free-fliers together in tandem.
Printed 2/21/17*



*Radiation Enclosure Module (REM) printed in different thicknesses to hold monitors for radiation testing.
Printed 3/20/17, 5/30/17, and 6/16/17*



Antenna Feed Horn which is being tested with various printed coatings for in-space use. Printed 3/9/17 and returned on SpaceX-10 3/20/17



Oxygen Generation System (OGS) Adapter attaches over air inlet to obtain a consistent and accurate reading of airflow. Printed on 7/19/2016



Let's Talk Trash...

Did you know....on the International Space Station, astronauts currently squeeze their garbage into trash bags and, for temporary periods of time, store up to **2 metric tons** of trash on board before burning it up on re-entry!!



The Refabricator...3D Printer and Recycler in ONE Package!!



- The Refabricator launched to the ISS in November 2018 and is now installed on-orbit. It is the first ever integrated 3D Printer and Recycler. This means that it can recycle a 3D Printed part back into filament (3D Printer “ink”) so that a brand new part can be made.
- By recycling parts, NASA won’t have to launch as much material or spare parts. Plastic bags, packing foam, and food containers can be recycled into new items!
- On Earth, this technology could use old water bottles and plastic bags from the grocery store to make filament capable of 3D printing all kinds of things!

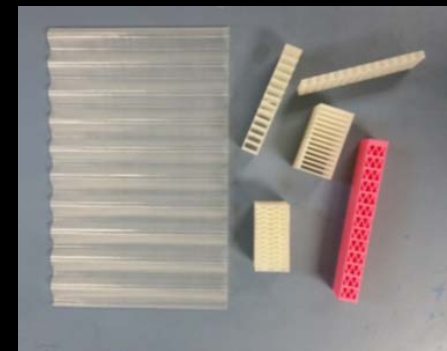
The Next Step...What does the future hold as far as Recycling in Space?

- **The 1st Generation Exploration Recycler, named ERASMUS, is being developed by Tethers Unlimited, Inc.**
- **ERASMUS will include not only a 3D Printer and Recycler, but also a dry-heat Sterilizer!**
- **ERASMUS will be able to fabricate and recycle polymer parts, including food containers and medical-grade items which make up a high percentage of trashed materials on the ISS.**
- **Lessons learned from the Refabricator Technology Demonstration are informing the design of ERASMUS.**



Thinking ahead...Designing packaging that can be easily recycled in Space

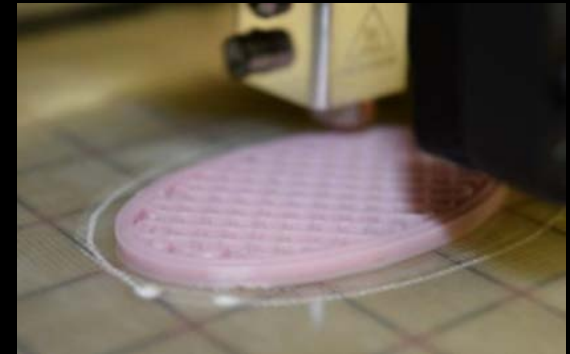
- Several logistics analyses have shown that having a recycling capability dramatically reduces initial launch mass requirements for long-duration missions.
- Current packaging materials for ISS represent a broad spectrum of polymers such as Low-density polyethylene (LDPE), HDPE, Polyethylene Terephthalate (PET), Nylon, and Polyvinyl Chloride (PVC).
- NASA ISM is collaborating with ISS packaging and Logistics Reductions teams to identify materials that can initially be used for packaging, then be recycled into useable feedstock for fabrication of parts during the mission.
- Customizable Recyclable ISS Packaging (CRISSP) is currently being developed by Tethers Unlimited, Inc. CRISSP is recyclable foam packaging that is 3D printed from thermoplastic materials. The packaging can be custom-printed with infill profiles that yield specific vibration characteristics or mechanical properties.



Images courtesy of Tethers Unlimited, Inc.

Enabling “Trash” Plastics to be Melted and Extruded into usable Filament

- **Cornerstone Research Group is focusing on the development of a reversible cross-linking additive (RVT). When RVT is heated up, it changes the viscosity of the melted plastic so that it can be extruded into filament for 3D printing.**
- **The addition of RVT to recycled plastics will allow various plastics that could previously not be melted and extruded into usable filament to now be of use in the manufacturing of new packaging, tools, and parts in space.**

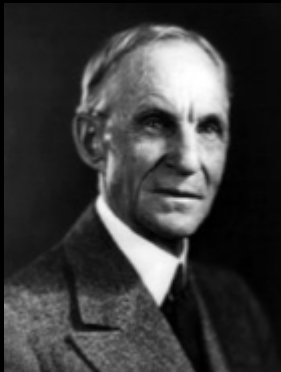


3D Printed Parts from Reclaimed Anti-static Bagging Film with the addition of RVT

Questions ?



...and if you break it, ISM can recycle it and remake it!



“IF I HAD ASKED PEOPLE
WHAT THEY WANTED,
THEY WOULD HAVE SAID:
FASTER HORSES...”

Henry Ford

“If what you’re doing is not seen by some people as science fiction, it’s probably not transformative enough.” -Sergey Brin

Acknowledgements



Contributor:

Niki Werkheiser: NASA MSFC In-Space Manufacturing, Project Manager