Advanced Manufacturing for NASA's Exploration Initiatives

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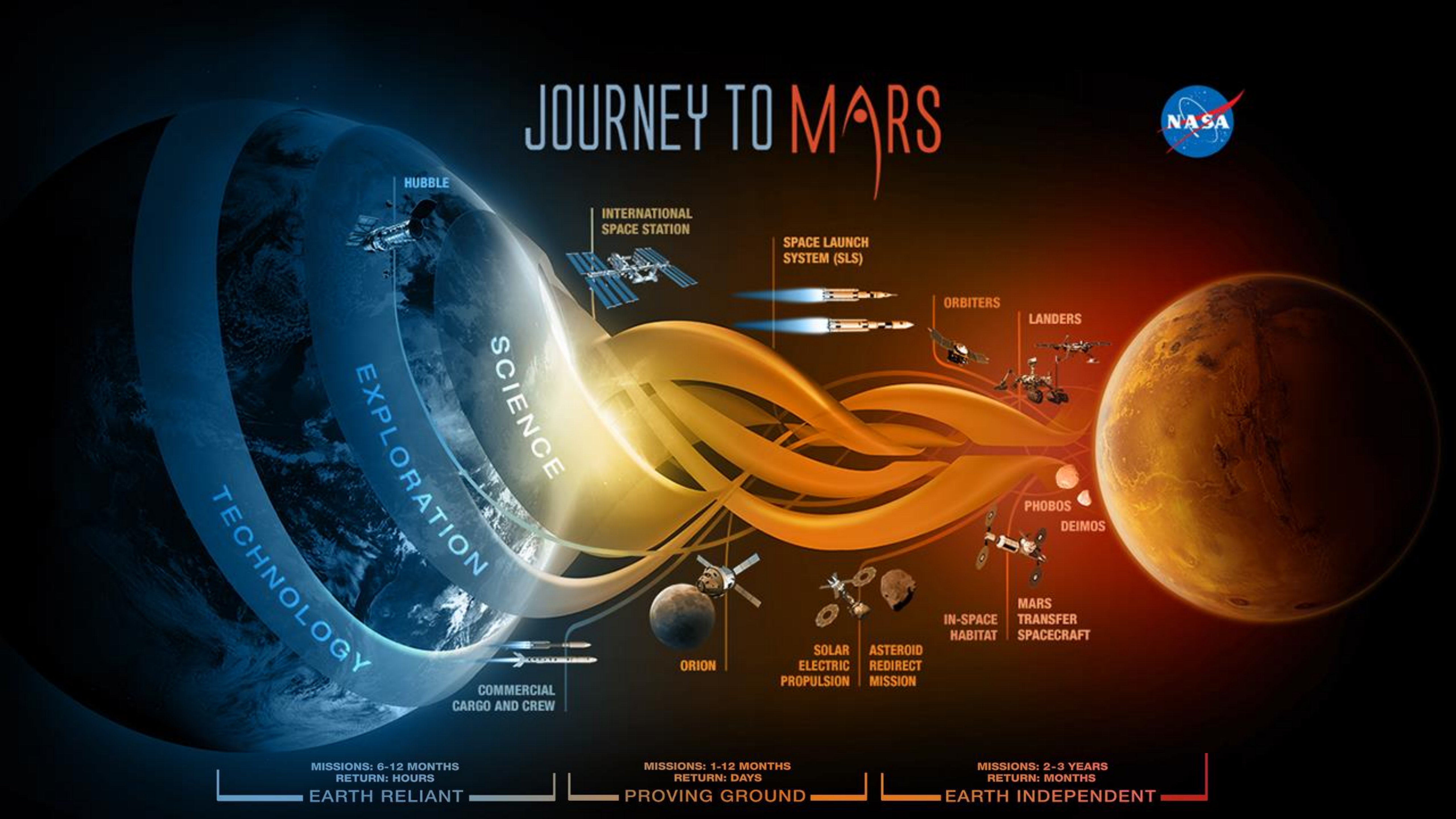
NASA Marshall Space Flight Center


JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
ORION
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
IN-SPACE HABITAT
MARS TRANSFER SPACECRAFT
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1-12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2-3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

NASA: Today Through Mid-2020s

NASA: 2018 – 2030s

PROVING GROUND

2018 - 2030

- Regular crewed missions and spacewalks in cislunar space.
- Verify deep space habitation and conduct a yearlong mission to validate readiness for Mars.
- Demonstrate integrated human and robotic operations by redirecting and sampling an asteroid boulder.

NASA: Moving into 2030s and Beyond

EARTH INDEPENDENT

NOW - 2030s & Beyond

- Science missions pave the way to Mars.
- Demonstrate entry, descent, and landing and in-situ resource use.
- Conduct robotic round-trip demonstration with sample return in the late 2020s.
- Send humans to orbit Mars in the early 2030s.

Manufacturing Technologies

NASA seeks to develop technologies that enable manufacturing…

… for space, … in space … and "in situ"

Metallics

Composites

Additive Manufacturing

Manufacturing to
Repair, Replace, Recycle

Earth-Independent
Manufacturing/Planetary
Construction

Friction Stir Welding

-Solid state welding process developed in 1991 in Cambridge, England and pioneered by NASA for aerospace applications

-Unique ability to join metal materials without melting

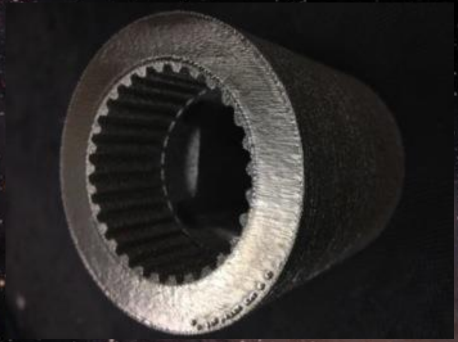
-Preserves properties of initial material in welded joint

-Currently used across the industry for launch vehicle structures (mostly fuel tanks)

Additive manufacturing technologies "for space"

Engine parts made with selective laser melting (SLM) process

Custom Tooling



Custom Instrumentation

Valve Housing

J-2X Gas Generator Duct

Pogo Z-Baffle

Turbopump Inducer

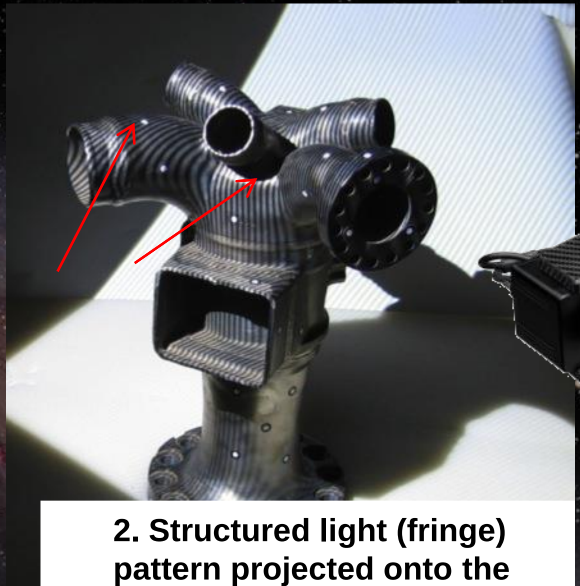
RS-25 Flex Joint

Reduces part count, number of welds, part lead time, and enables "manufacturing for design"

Structured Light Scanning

- *scanning technique used to three-dimensionally reconstruct an object*
- *Can compare as-built part with desired/nominal geometry*
- *Reverse engineering a part for which no drawings exist*
- *Assess dimensional variability between parts*

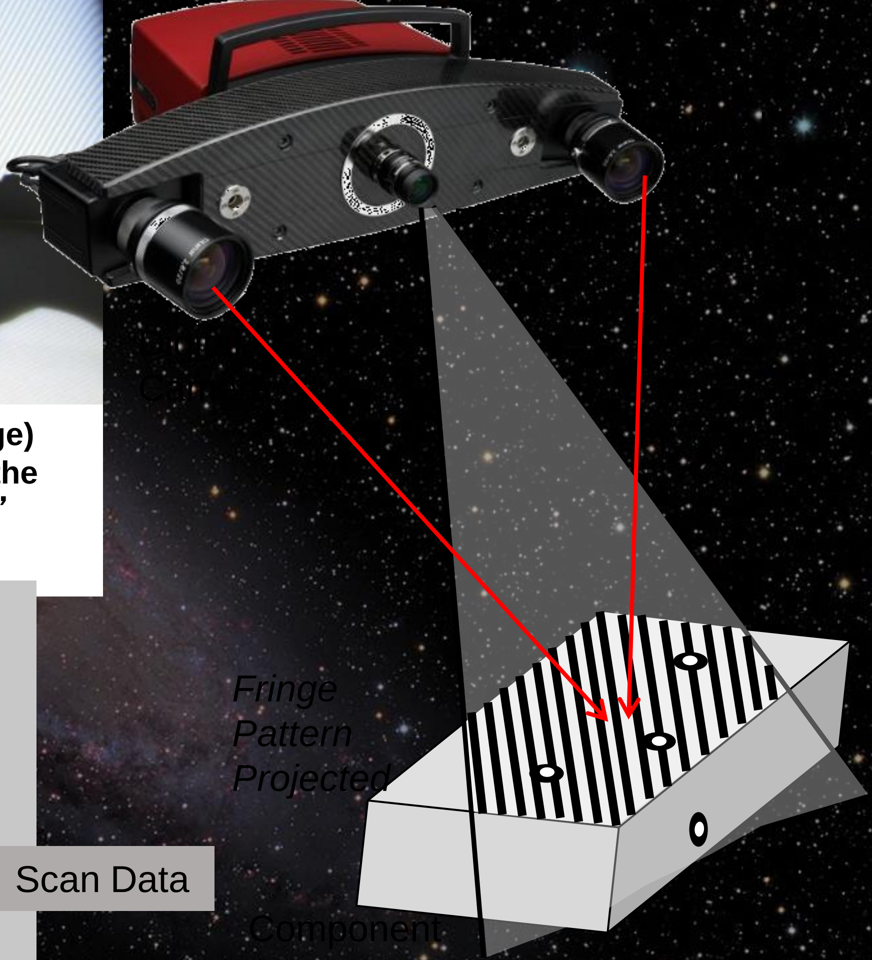
1. Targets are placed on the hardware



2. Structured light (fringe) pattern projected onto the component that "shifts" rapidly

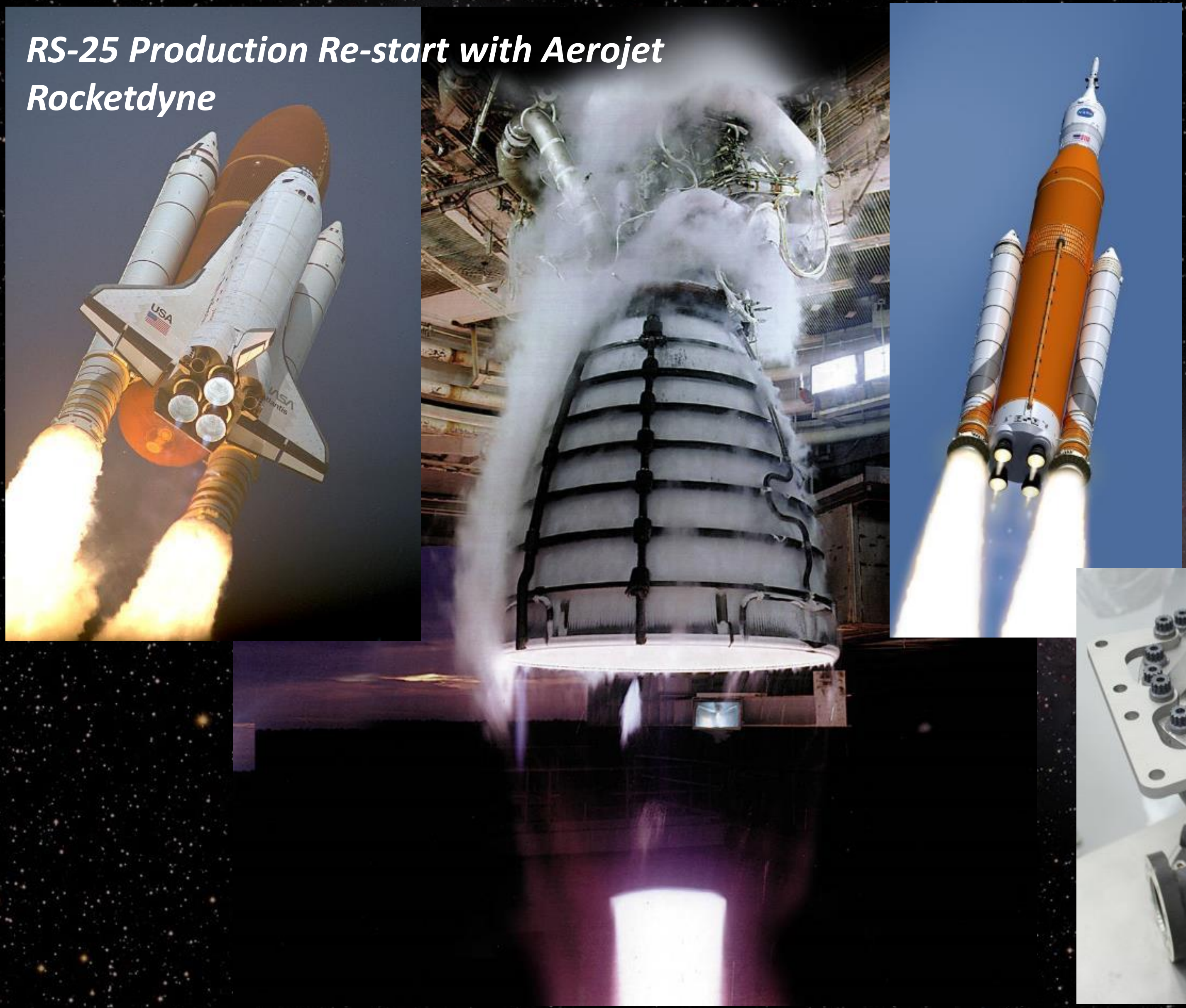
Digital Photo

Scan Data

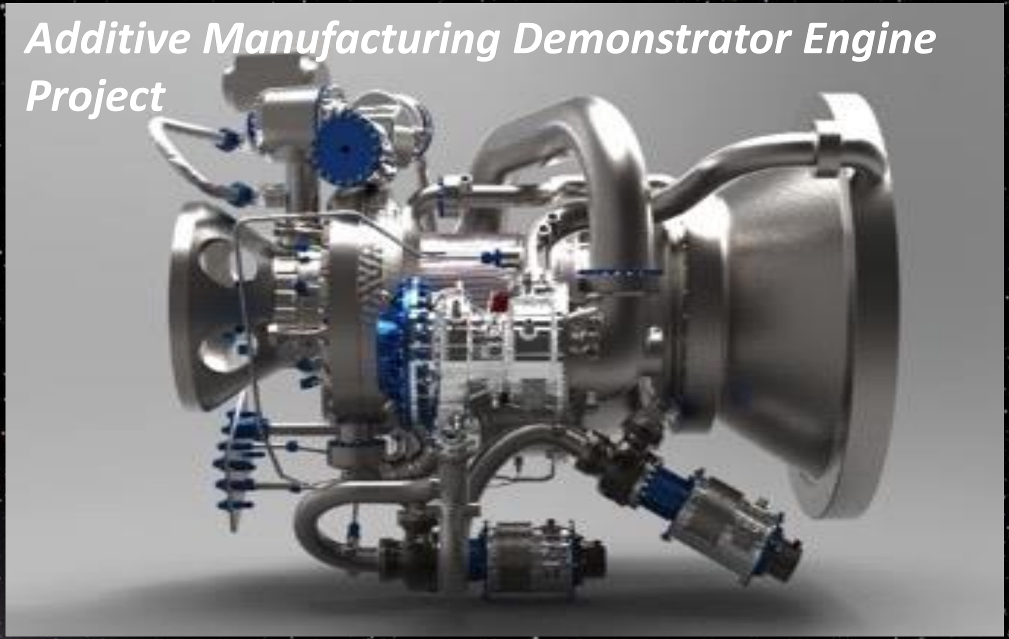


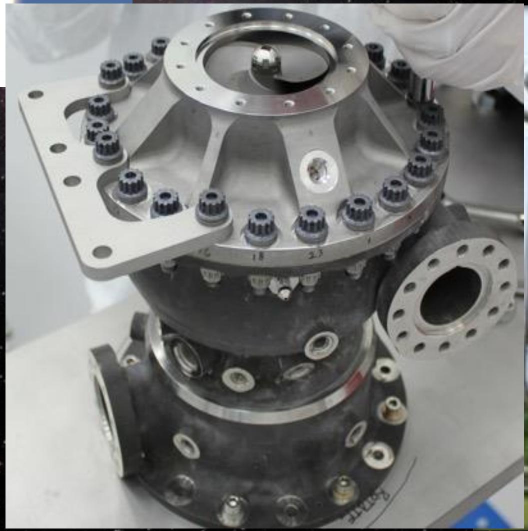
Additive Technologies – Two Aerospace Applications

RS-25 Production Re-start with Aerojet Rocketdyne



Additive Manufacturing Demonstrator Engine Project

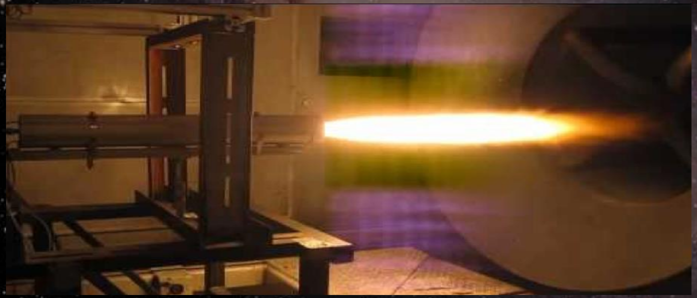




Additive Technologies Enabling New Propulsion Concepts

- ***3D printed fuel grains for hybrid thrusters (joint effort between NASA and Utah State University)***
- ***Alternative to expensive and toxic (hydrazine) systems currently used in small satellite applications***

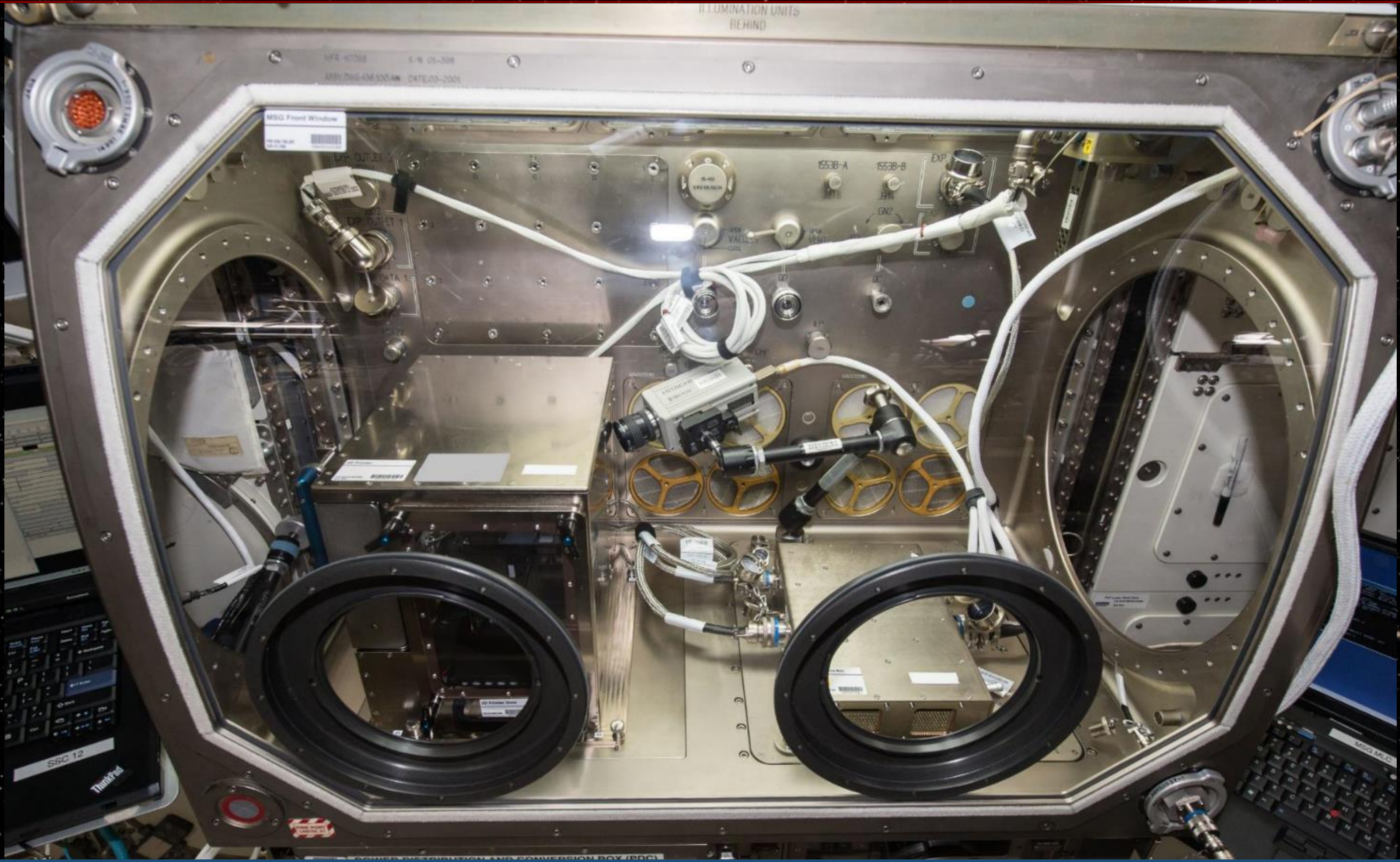
Additively-manufactured fuel grain of ABS. 3-D printed ABS has the unique ability to concentrate minute electrical charges on its surface when subjected to a low energy inductive spark.



Flight Weight Arc-Ignition "Green" Thruster System undergoes testing in vacuum chamber

Flight demonstration of technology next summer on sounding rocket launched from NASA Wallops; current focus on developing more combustible filament blends for 3D printing

Additive Manufacturing In Space



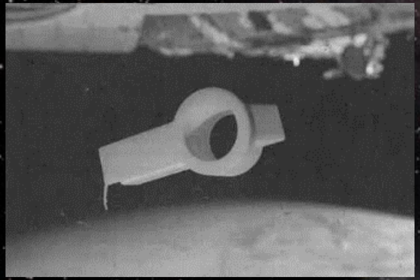
In-Space Manufacturing 3D Printing in Zero-G Technology Demonstration Onboard the ISS

Additive Manufacturing In Space

SPHERES Tow Hitch

REM Shield Enclosure

Antenna Feed Horn



OGS Adapter

Mechanical Property Test Articles

Tensile

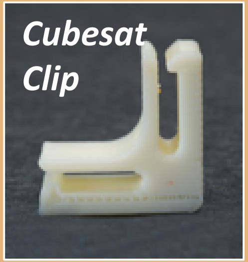
Compression

Flex

Functional Tools

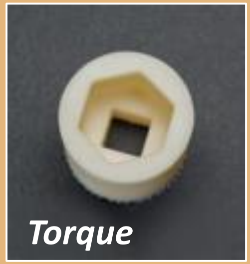
Crowfoot

Ratchet



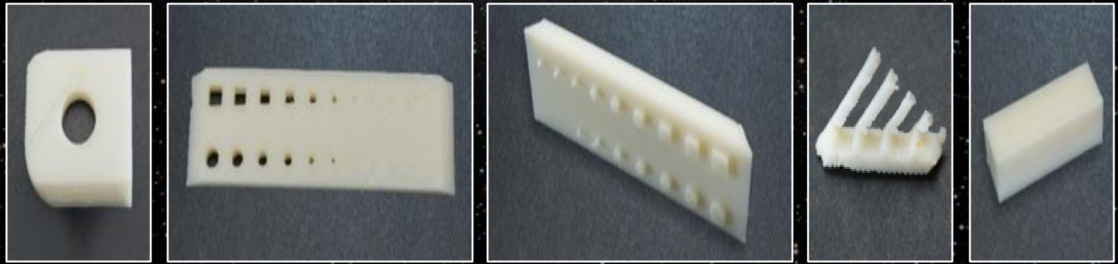
Cubesat Clip

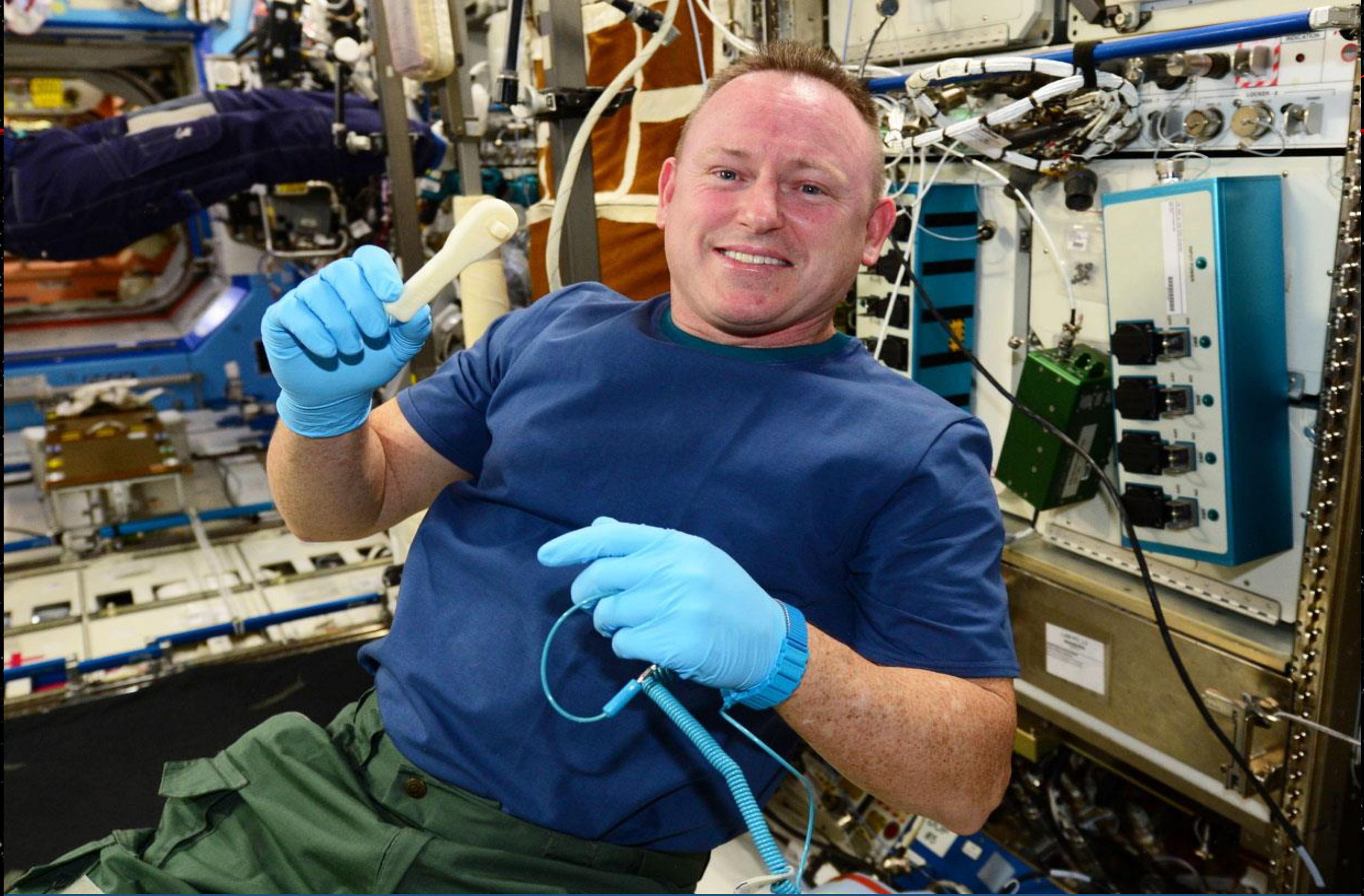
Container



Torque

Printer Performance Capability

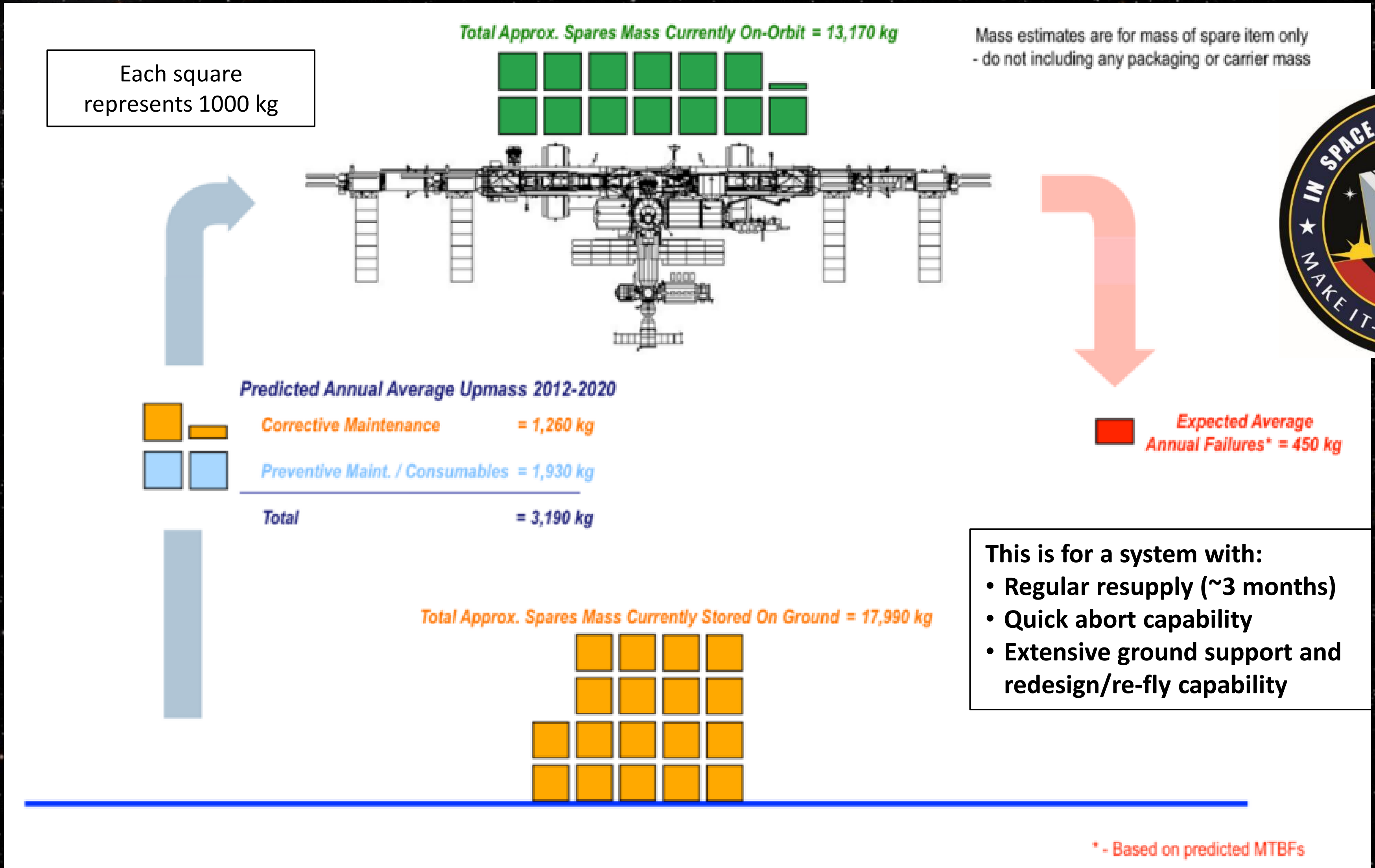




ISS Commander Butch Wilmore holding a Ratchet that was 3D Printed Onboard the ISS

Manufacturing in-space: Why?

- ***Based on historical data, 95% of spares will never be used***
- ***Impossible to know which spares will be needed***
- ***Unanticipated system issues always appear, even after years of testing and operations***



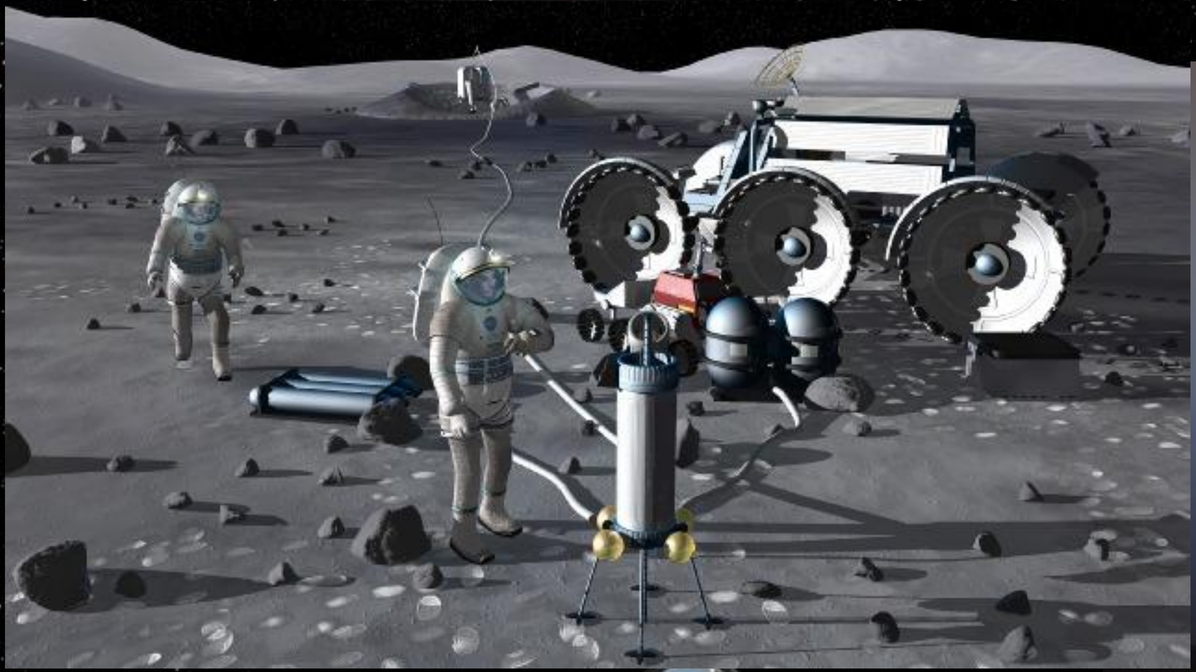
This is for a system with:

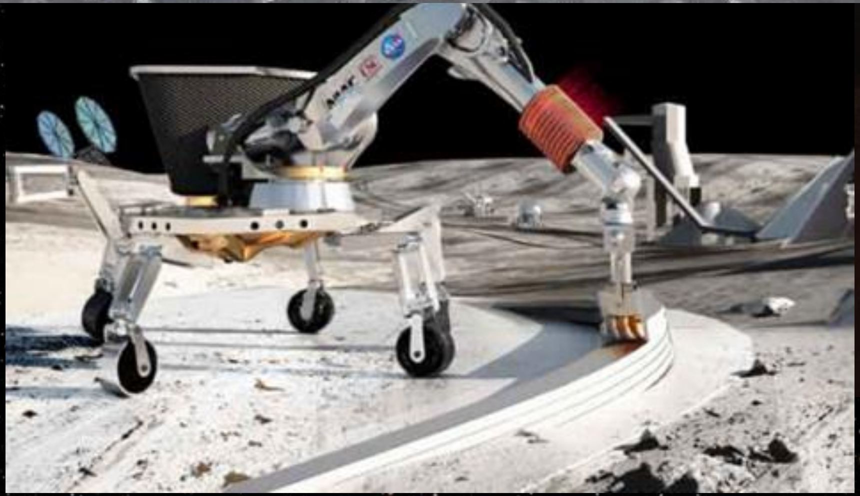
- Regular resupply (~3 months)
- Quick abort capability
- Extensive ground support and redesign/re-fly capability

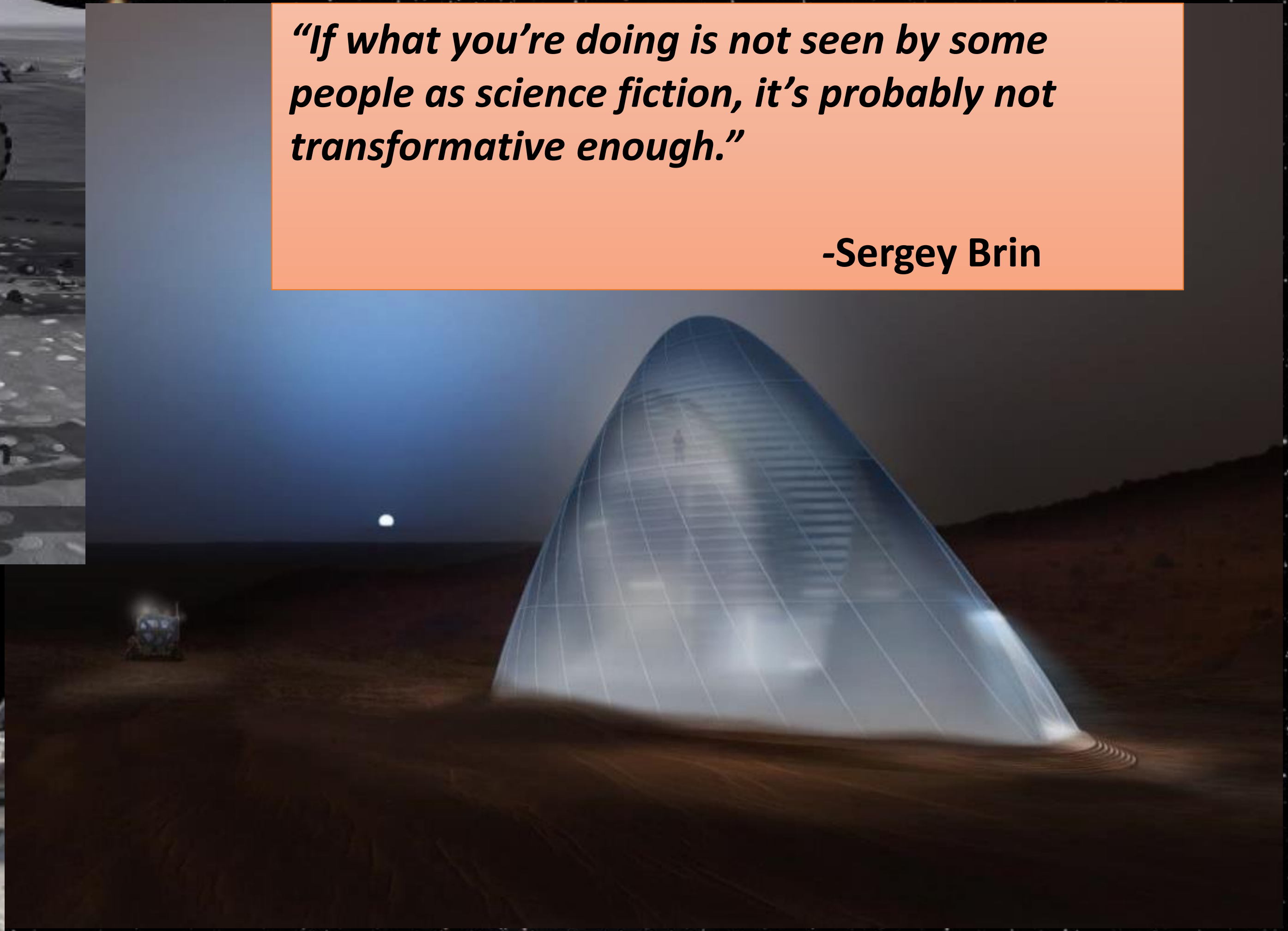
Multimaterial Fabrication Laboratory for ISS

- *FabLab will begin development in late 2017 and will be a design and demonstration of a first-generation in-space manufacturing fabrication laboratory*
- *Minimum target capabilities:*
  - *Manufacturing of metals*
  - *Meet ISS requirements for power and volume*
  - *Limit crew time*
  - *Incorporate remote and autonomous verification and validation of parts*

Manufacturing "In Situ"







"If what you're doing is not seen by some people as science fiction, it's probably not transformative enough."

-Sergey Brin

Centennial Challenge: 3D Printed Habitats

- *Centennial Challenges is NASA's prize competition program*
- *3D Printed Habitat Challenge asks teams to develop 3D-printable materials from recyclables (plastics) and regolith (materials on planetary surfaces like the Moon or Mars), demonstrate the strength of the material, and develop systems that can produce full-scale structures*

3D-printed compression cylinder made from a polymer and lunar regolith simulant (image from Branch Technologies and Foster + Partners)

3D-Printing system developed by University of Alaska Fairbanks for the Centennial Challenge

3D-Printed beam (polymer/regolith mix) test specimen from Oregon State University www.nasa.gov