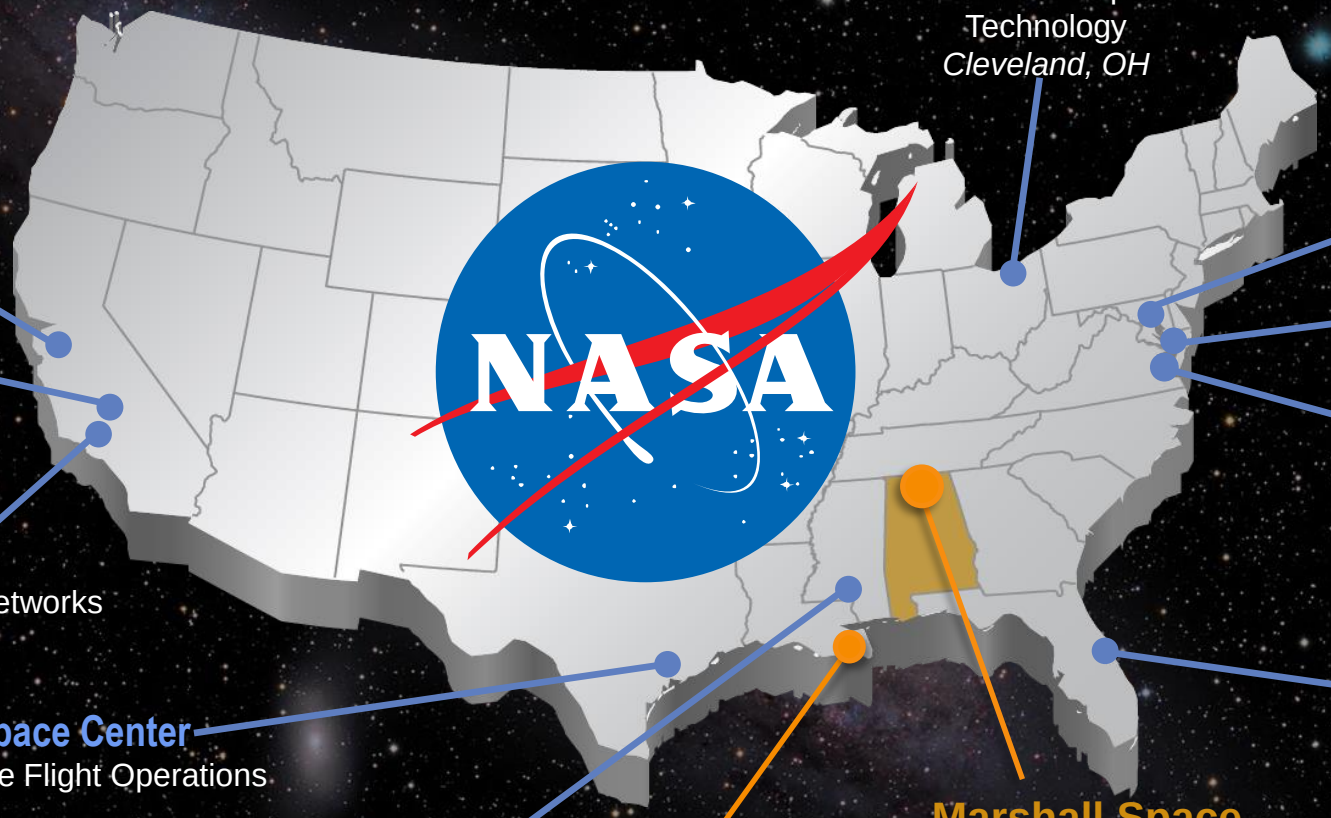
The Role of Advanced Manufacturing in Our Journey to Mars

Andrew S. Keys, Ph.D.
NASA Marshall Space Flight Center
22 February 2017
Catalyst Connection Annual Manufacturing Reception
Pittsburg, PA

NASA Field Center Locations



Glenn Research Center
Aeronautics and Spacecraft Technology
Cleveland, OH

Goddard Space Flight Center
Science Missions and Telescopes
Greenbelt, MD

Ames Research Center
Aerospace and Small Spacecraft
Moffett Field, CA

NASA Headquarters
Washington, D.C.

Armstrong Flight Research Center
Atmospheric Research and Testing
Edwards, CA

Langley Research Center
Aviation and Space Research
Hampton, VA

Jet Propulsion Laboratory
Deep Space Robotic Rovers and Networks
Pasadena, CA

Johnson Space Center
Human Space Flight Operations
Houston, TX

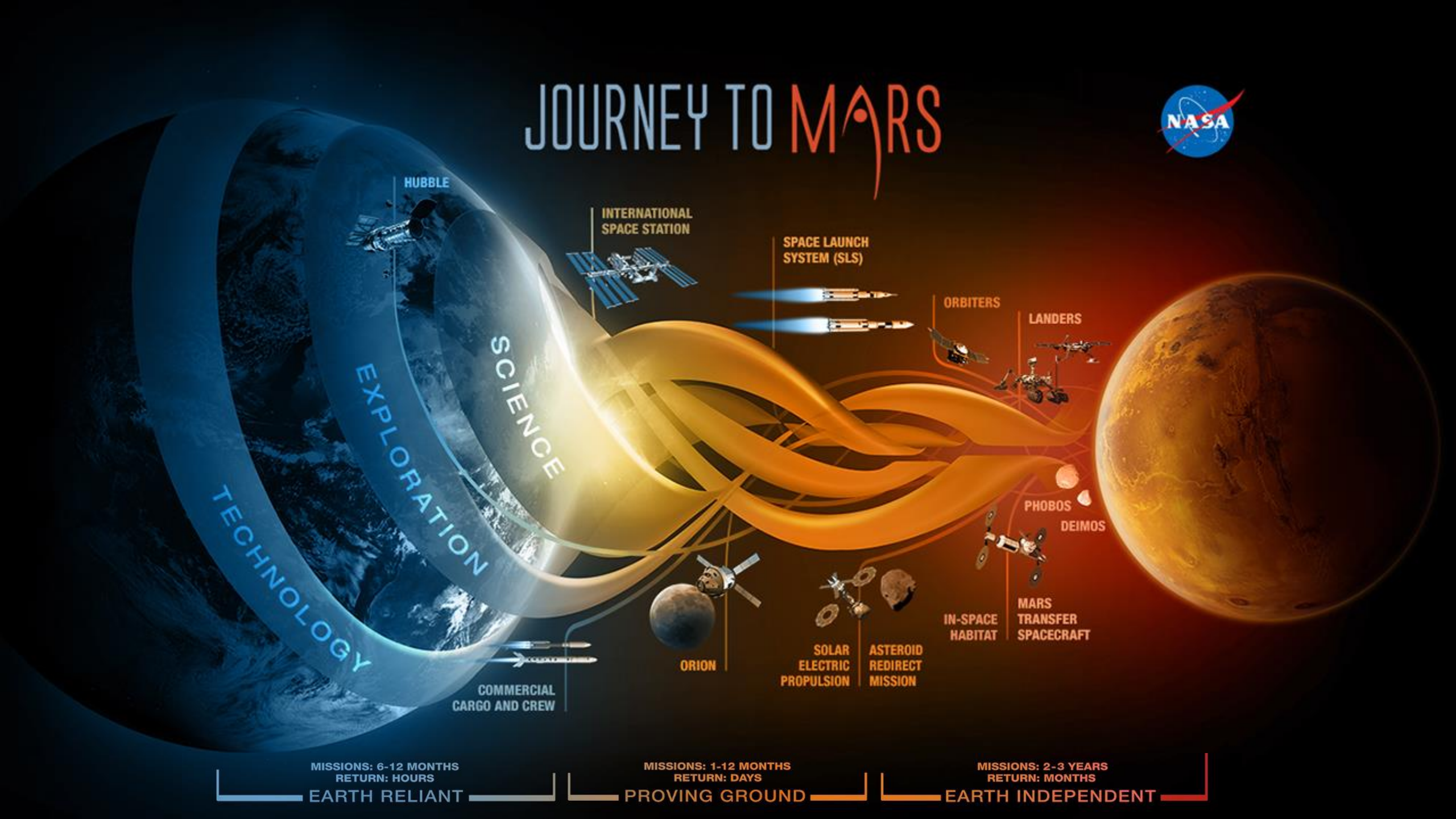
Kennedy Space Center
Space Vehicle Launch and Landing
Cape Canaveral, FL

Stennis Space Center
Vehicle Engine Testing
Bay St. Louis, MS

Michoud Assembly Facility
Large Vehicle Manufacturing
New Orleans, LA

Marshall Space Flight Center
Space Transportation, Propulsion Systems, Space Systems, and Science
Huntsville, AL

NASA Mission Directorates


JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
IN-SPACE HABITAT
MARS TRANSFER SPACECRAFT
ORION
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
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

EARTH RELIANT

NOW - MID-2020s

- International Space Station operation through 2024,
- Commercial development of low-Earth orbit.
- Development of deep space systems, life support and human health

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.

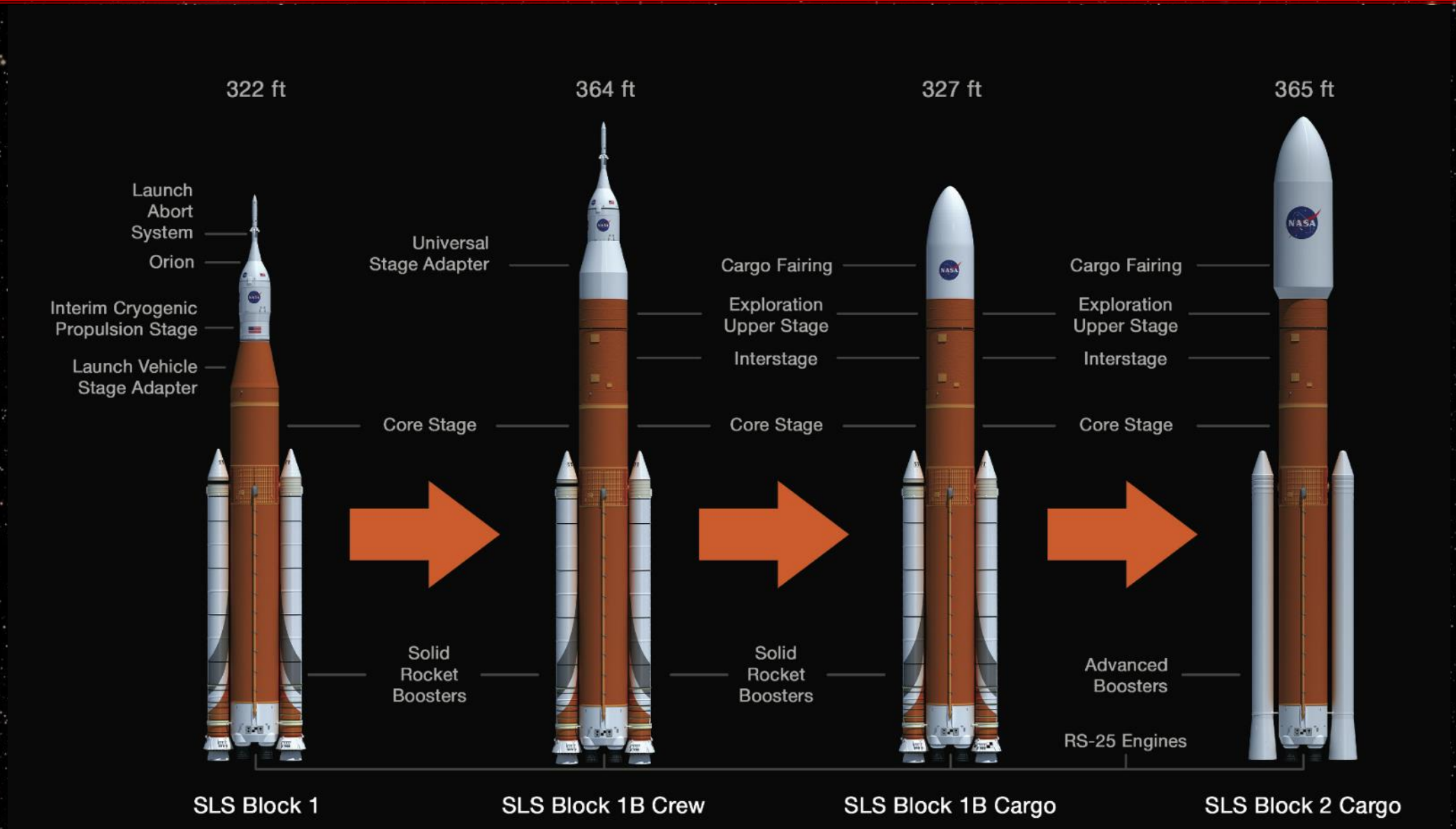
NASA: Moving into 2030s and Beyond

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.

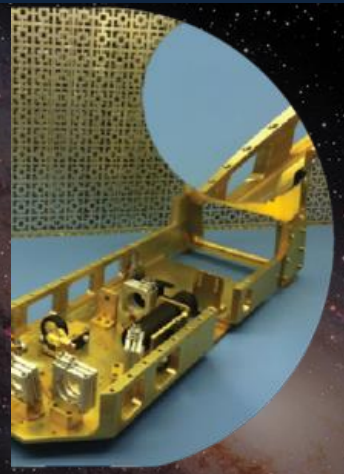
Evolution Plans for Space Launch System (SLS)



NASA's Space Technology Themes

Space Technology focus investments in 7 thrust areas that are key to future NASA missions and enhance national space capabilities.

Space Power and Propulsion



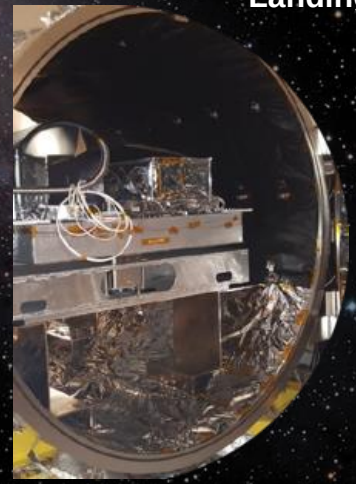
High-Bandwidth Comm, Deep Space Navigation, Avionics

Advanced Life Support & Resource Utilization

Entry Descent and Landing Systems

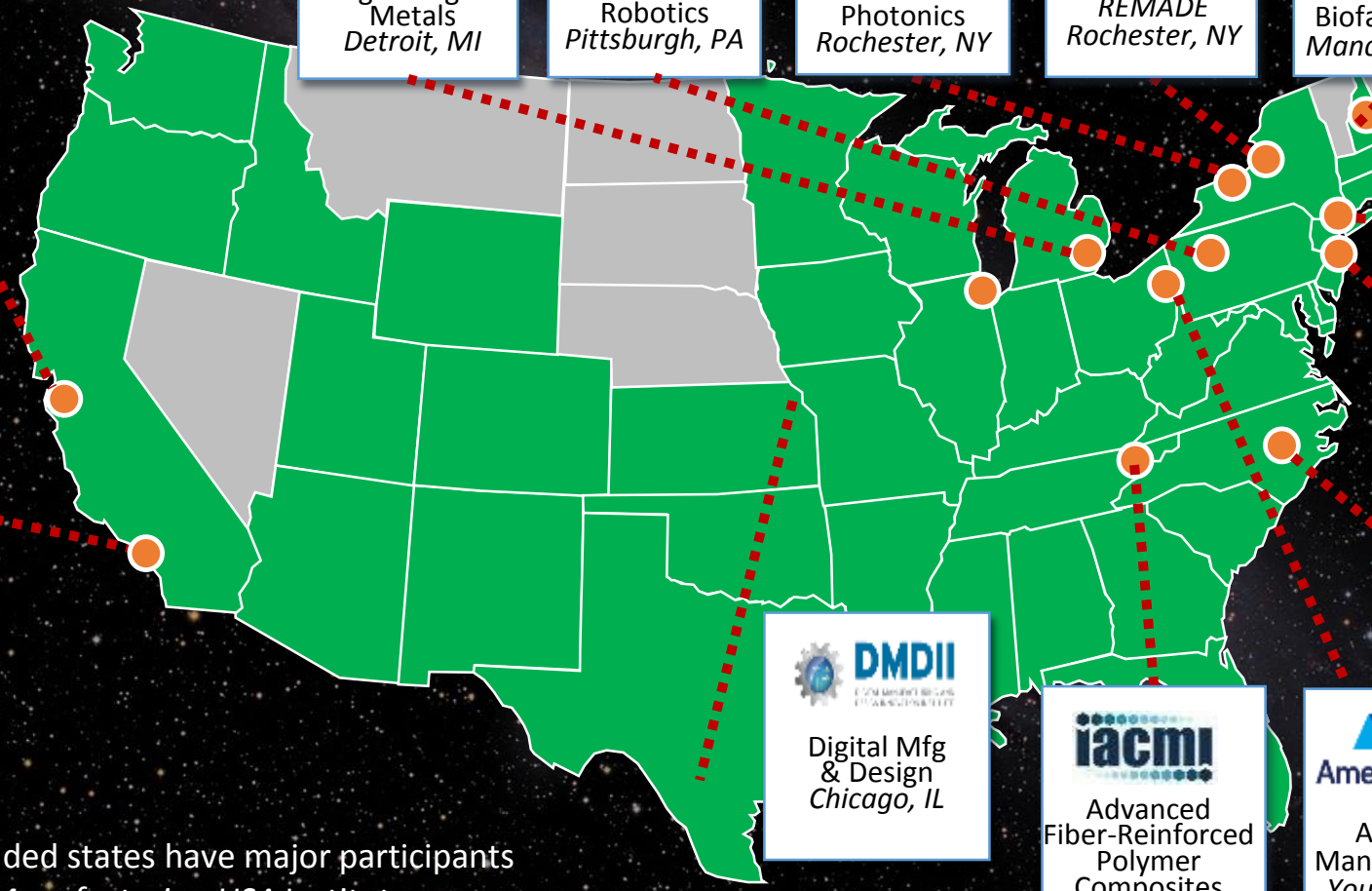
Autonomy & Space Robotic Systems

Lightweight Structures & Manufacturing



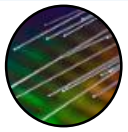
Space Observatory Systems

Manufacturing USA: Today



Lightweight Metals
Detroit, MI

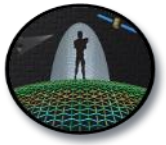
Advanced Robotics
Pittsburgh, PA



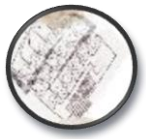
AIM Photonics
Rochester, NY

REMADE
Rochester, NY

Advanced Tissue Biofabrication,
Manchester, NH



AFFOA - Fibers and Textiles,
Cambridge MA



Flexible Hybrid Electronics
San Jose, CA

Smart Manufacturing
Los Angeles, CA

Modular Chemical Process Intensification
New York, NY

Bio-pharmaceutical Manufacturing
Newark, DE

Digital Mfg & Design
Chicago, IL

Advanced Fiber-Reinforced Polymer Composites
Knoxville, TN

Additive Manufacturing
Youngstown, OH

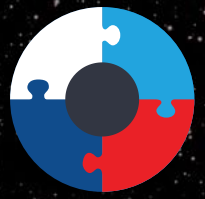
Wide Bandgap Semiconductors
Raleigh, NC

Shaded states have major participants in *Manufacturing USA* Institutes

Introduction to National Additive Manufacturing Innovation

America Makes
National Additive Manufacturing Innovation Institute

The National Additive Manufacturing Innovation Institute was launched in August 2012 as a result of President Obama's proposed need for a whole-of-government advanced manufacturing effort.



Mission: To accelerate the adoption of additive manufacturing technologies to increase domestic manufacturing competitiveness.

Funding: Five federal agencies - the Departments of Defense, Energy, and Commerce, the National Science Foundation, and NASA – jointly committed to invest $45 million.

NASA contributes subject matter experts, meaningful data, and use of select facilities.

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

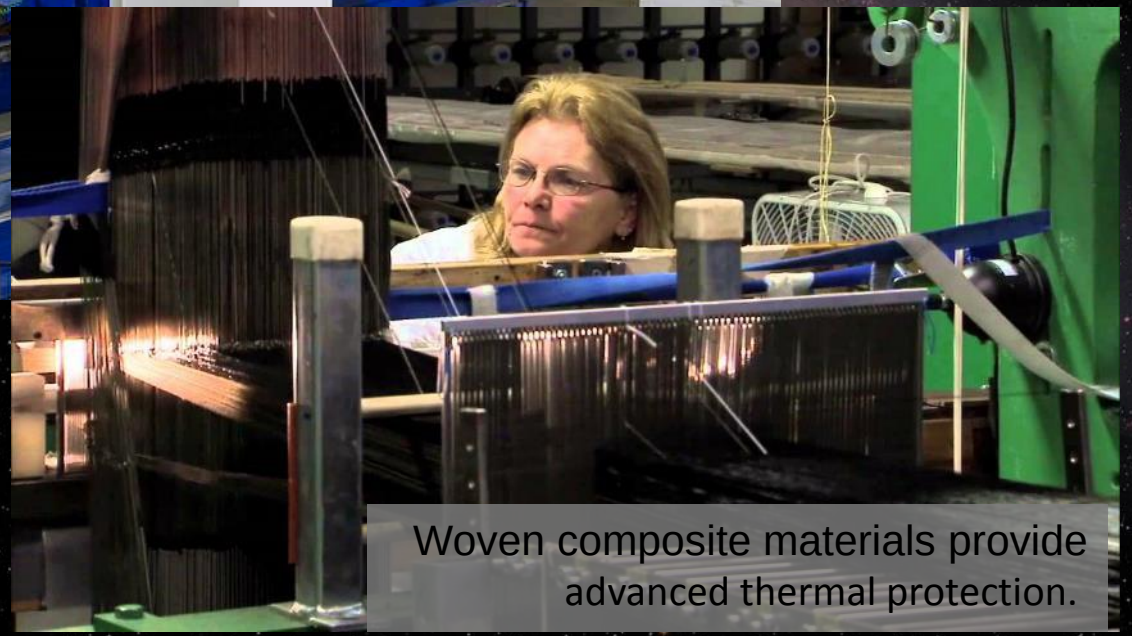
Earth-Independent
Manufacturing

Metallics and Welding Technologies for Space

Metallics and Welding Technologies for Space

Metallics and Welding Technologies for Space

Composite Technologies for Space

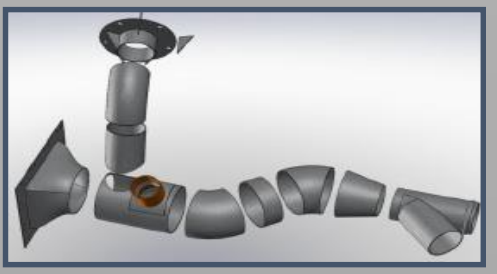


Woven composite materials provide advanced thermal protection.

Composite Technologies for Space

Why additive manufacturing?

- Enables Mass Production and Customization
- Rapid Manufacturing: Tool-less, Extreme Cycle Time Reductions
- Weight removal increases mission capabilities, saves fuel costs
- Enables complex designs and unitized structures



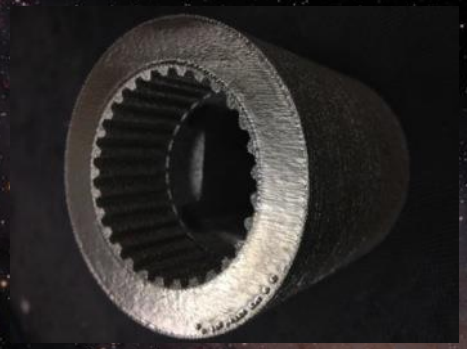
Traditional Part:
19 aluminum parts welded together

Additive Manufacturing Part:
1 part
30 % weight reduction
Cost and lead time reductions

Additive Technologies for Space

J-2X Gas Generator Duct

Custom Tooling

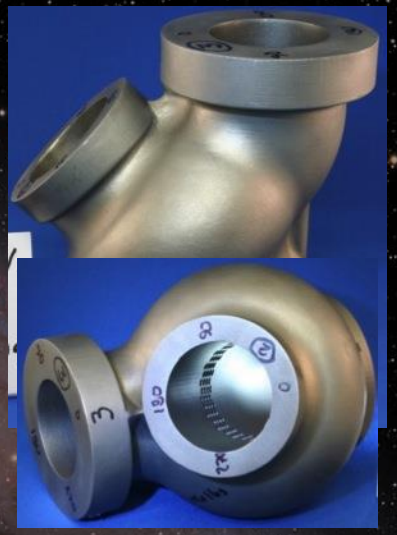


Pogo Z-Baffle

Turbopump Inducer

Custom Instrumentation

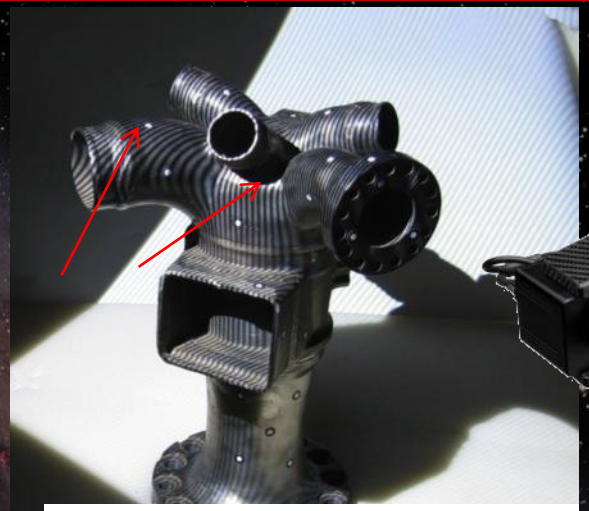
Valve Housing



RS-25 Flex Joint

Structured Light Scanning

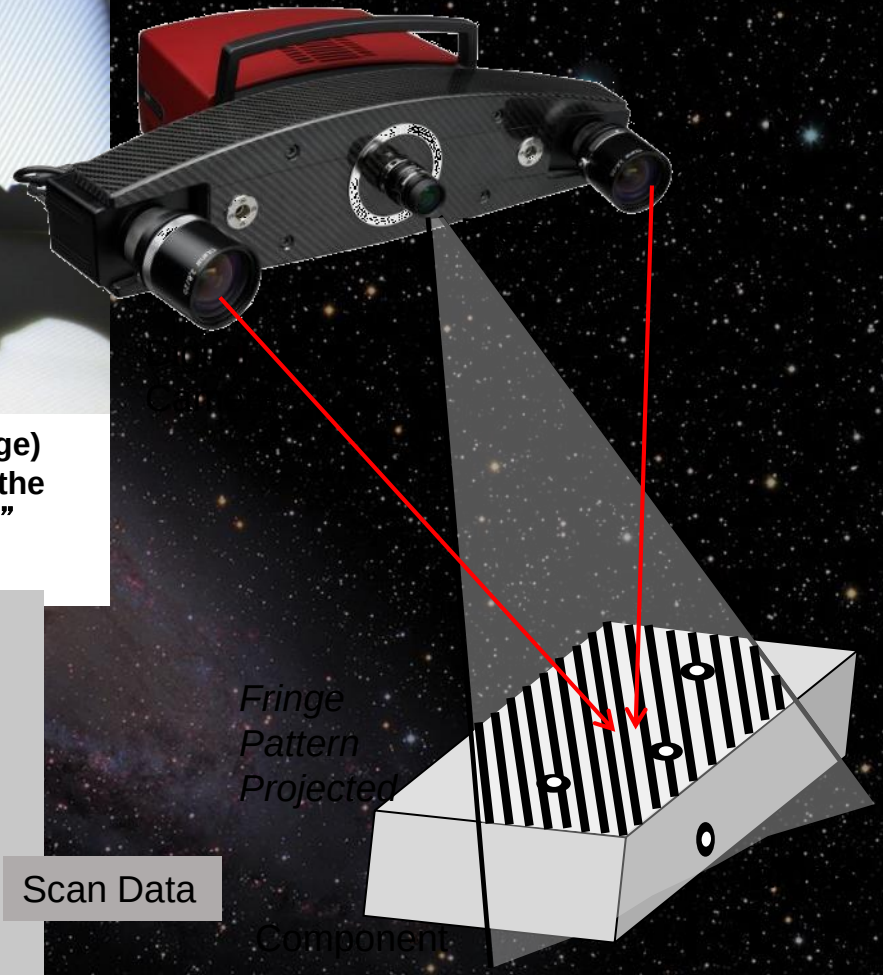
1. Targets are placed on the hardware



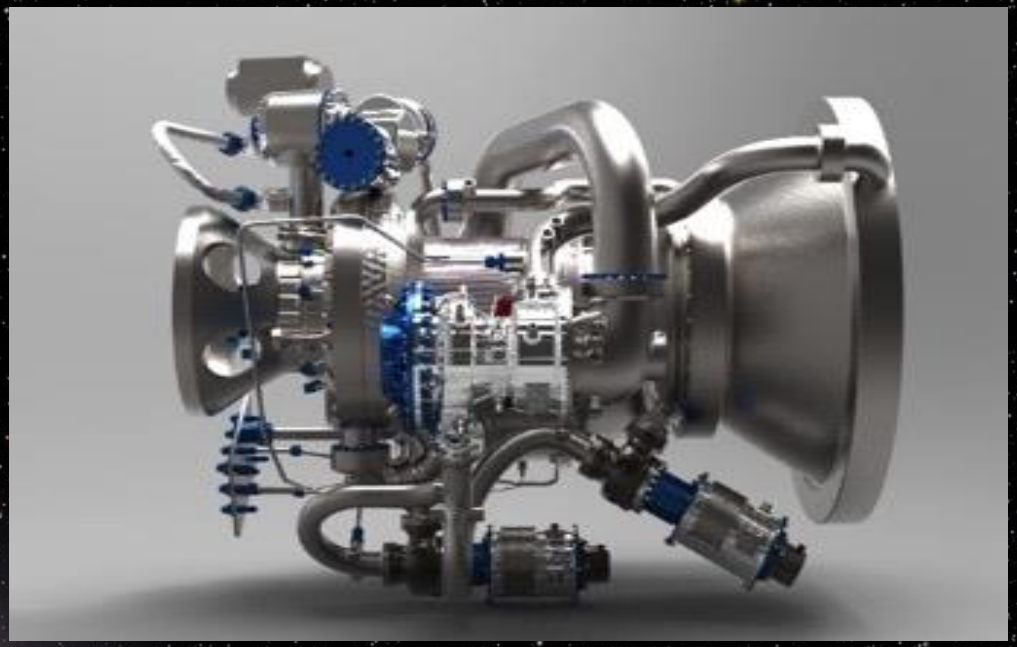
2. Structured light (fringe) pattern projected onto the component that “shifts” rapidly

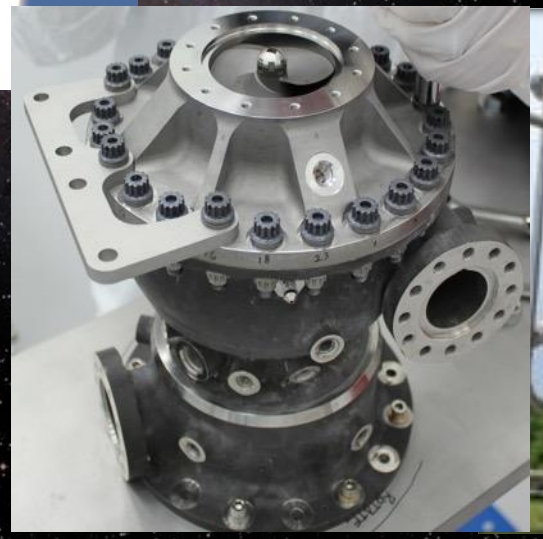
Digital Photo

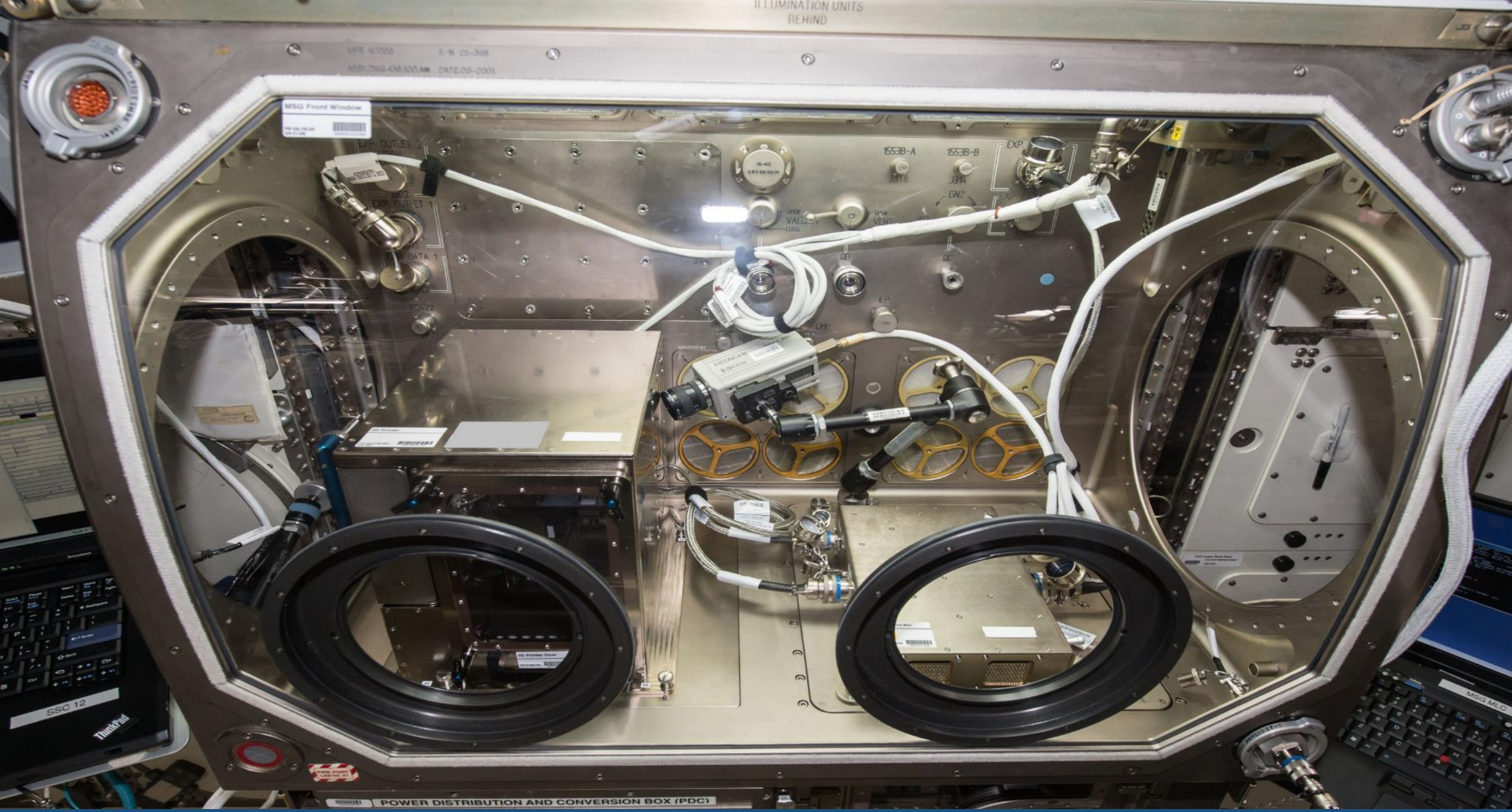
Scan Data



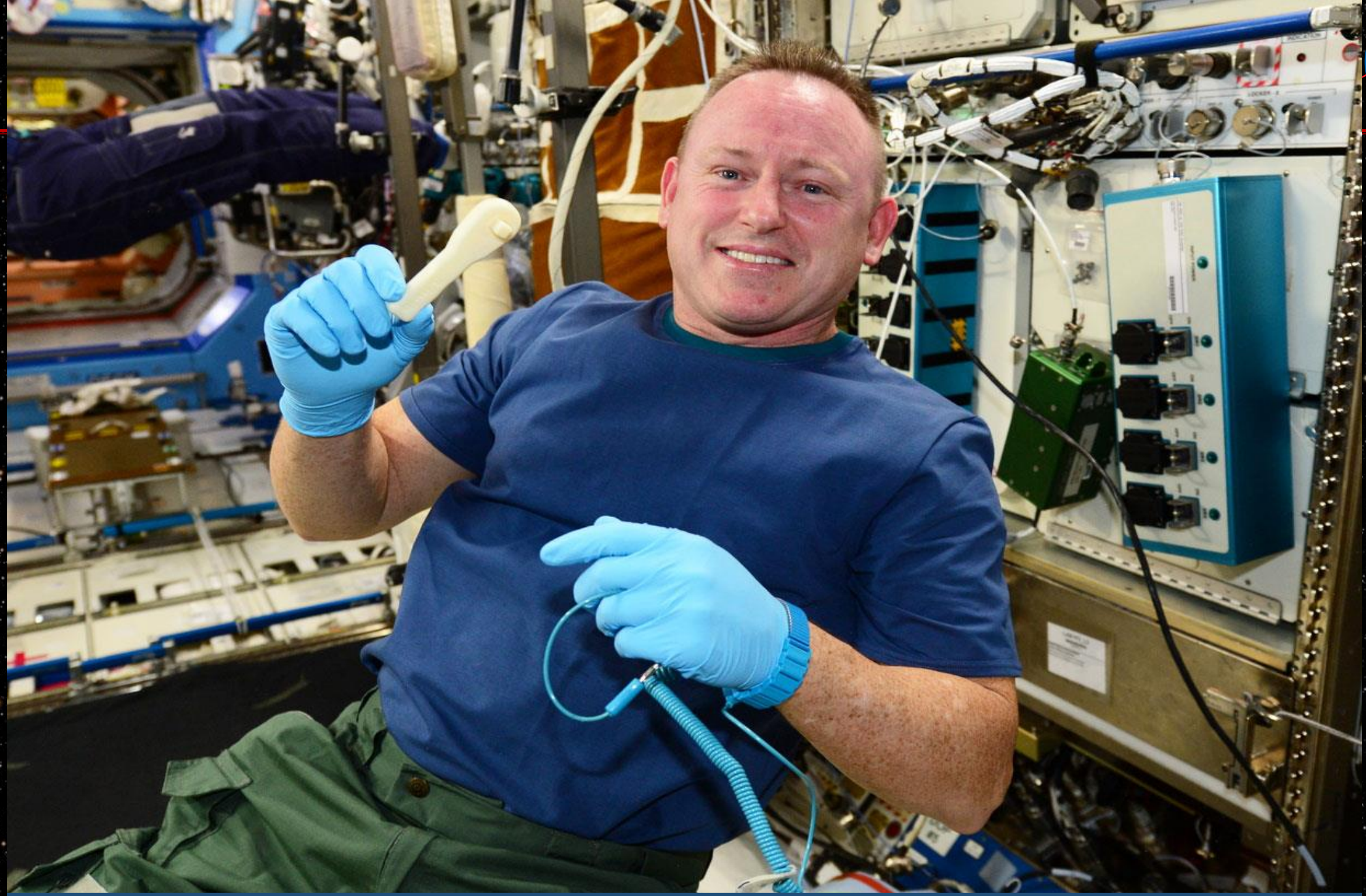
Additive Technologies – An Aerospace Application







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



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

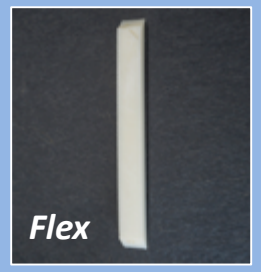
Completed Phase 1 Technology Demonstration Goals

- Demonstrated critical operational function of the printer
- Completed test plan for 42 ground control and flight specimens
- Identified influence factors that may explain differences between data sets

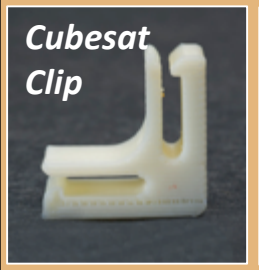
Phase II - TBD

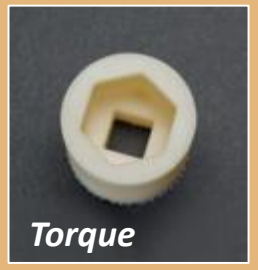
- Better statistical sampling
- Demonstrate critical maintenance functions of printer

Mechanical Property Test Articles

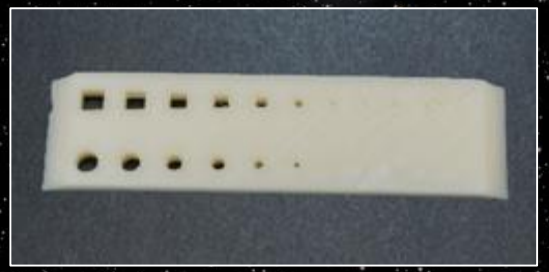


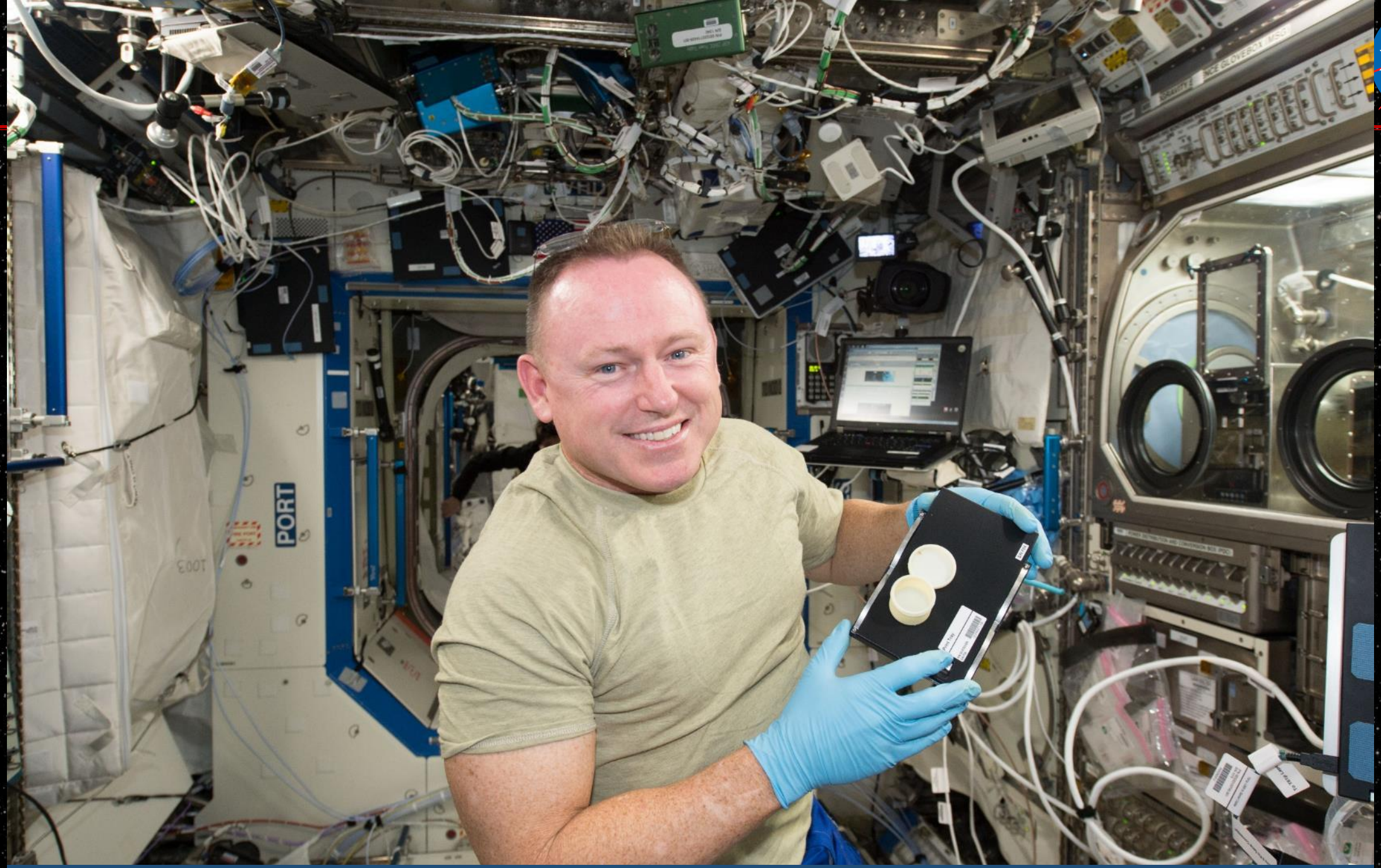
Functional Tools





Cap



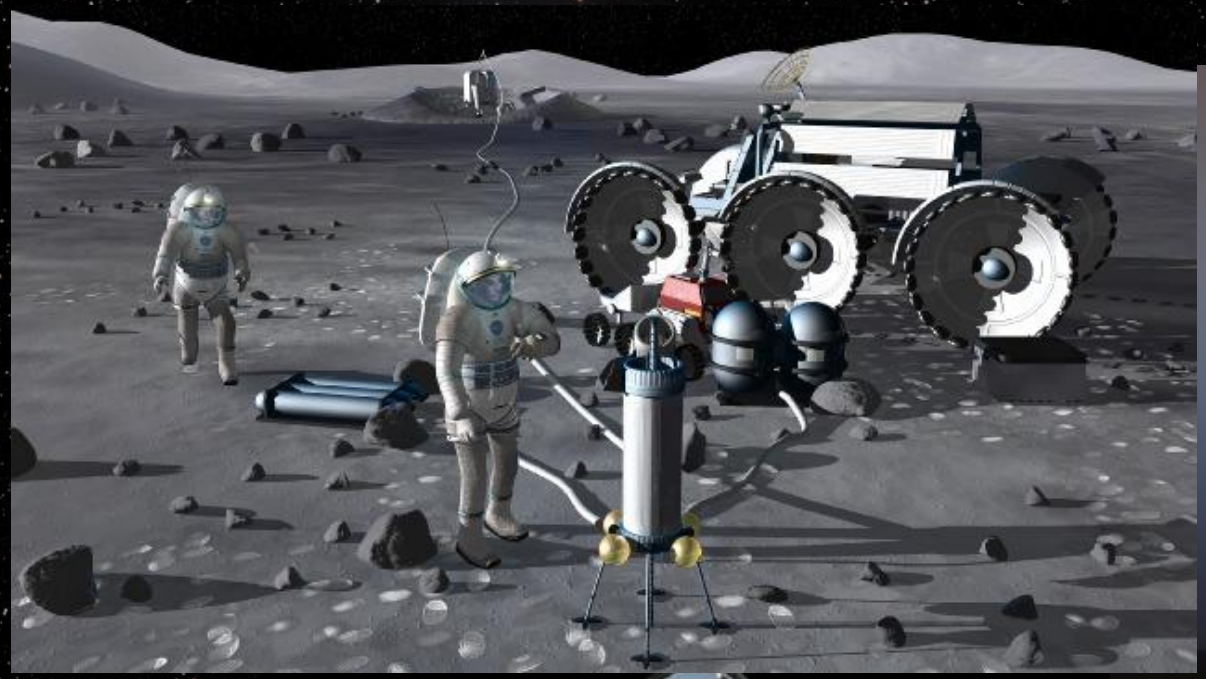


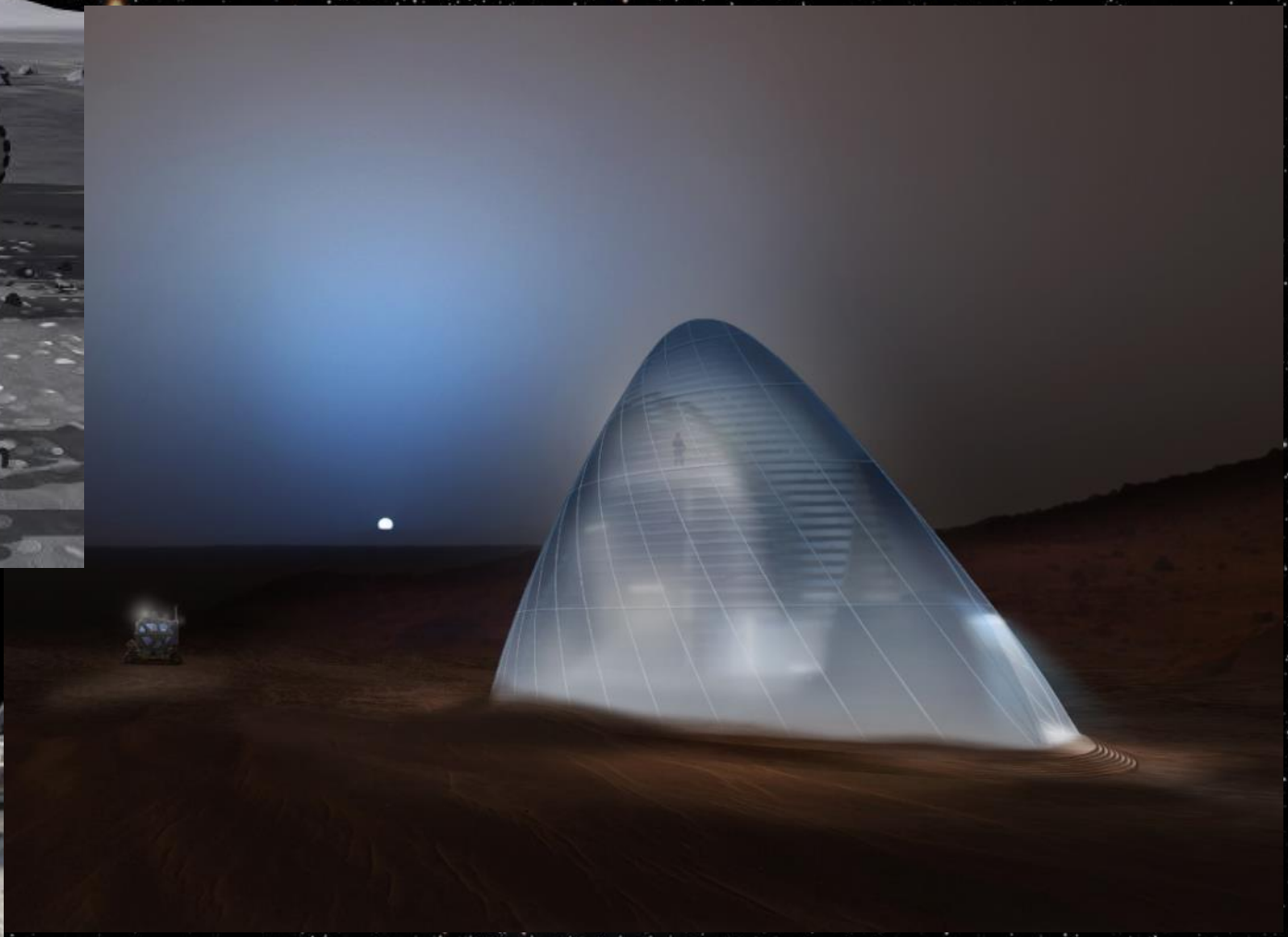
ISS Commander Butch Wilmore with a 3D Printed Sample Container Onboard the ISS

ISS Commander Butch Wilmore with a Sample Container that was 3D Printed Onboard the ISS

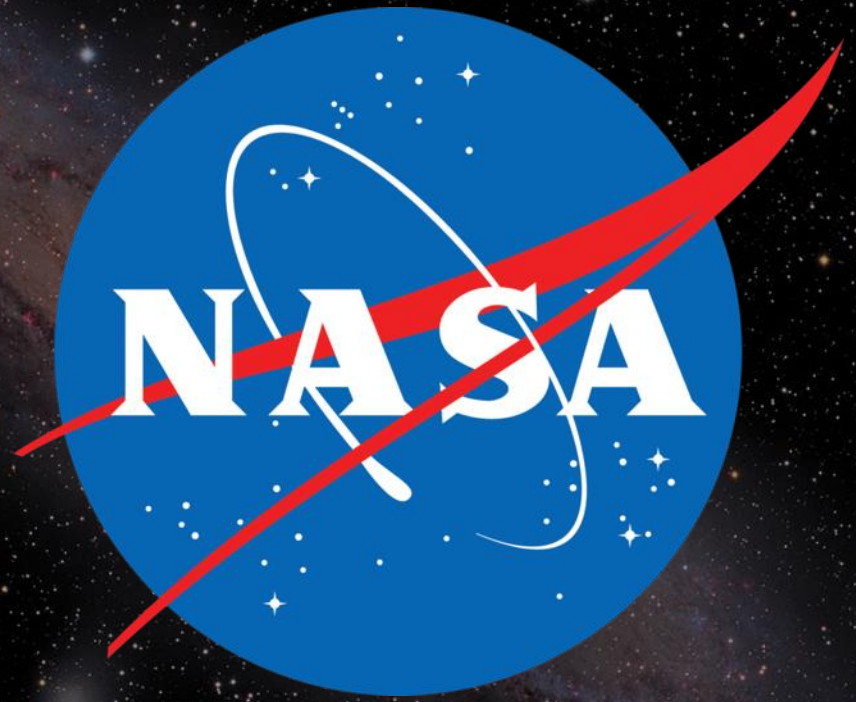
Student Designed Part Printed on ISS

Manufacturing “In Situ”





The Journey Continues…



www.nasa.gov