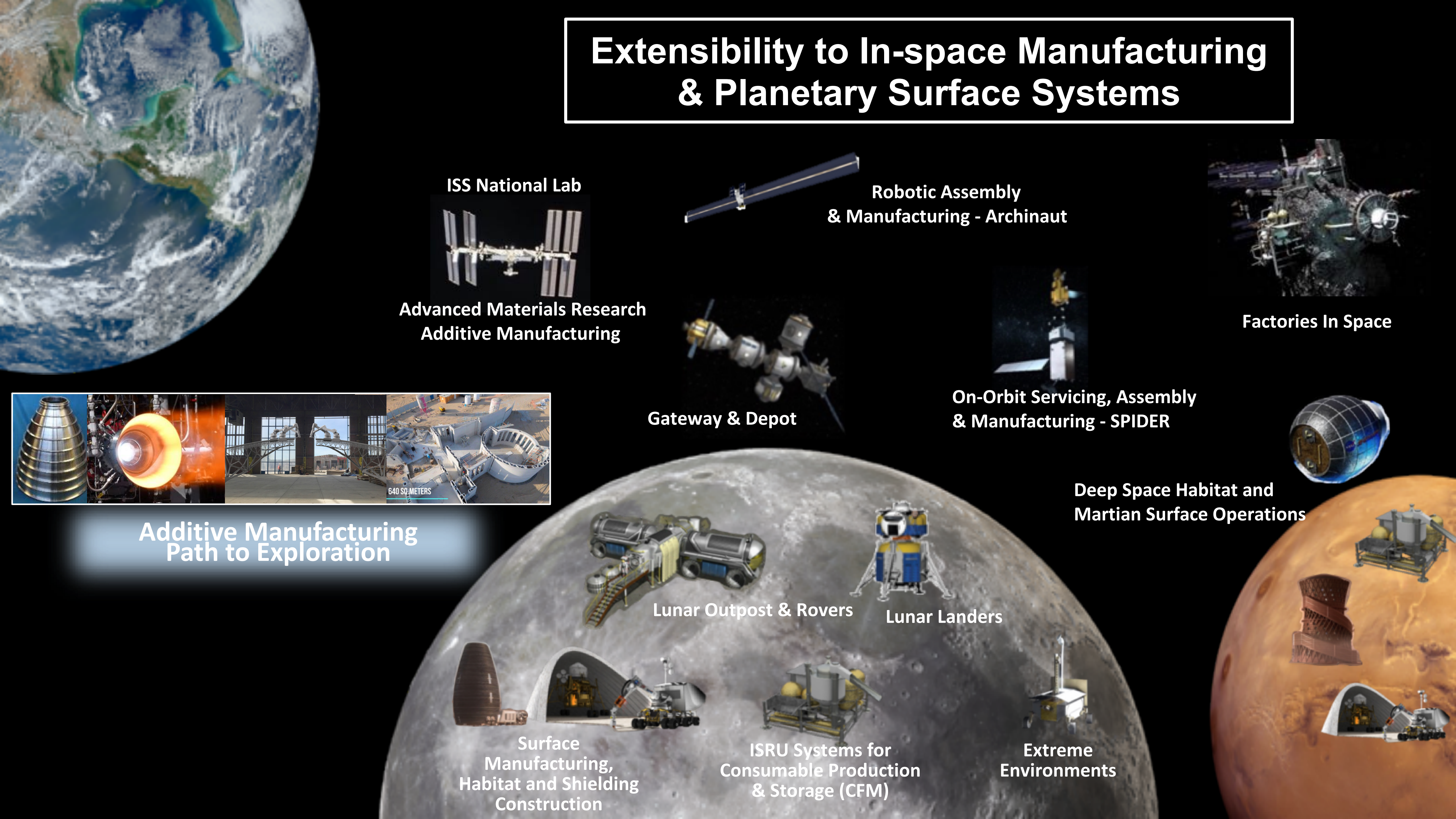
NASA's Additive Manufacturing Technology - Driving Exploration

Lunar Excavation, Manufacturing, and Construction Challenge - Ideation workshop

John Vickers, Principal Technologist | 02.20.20



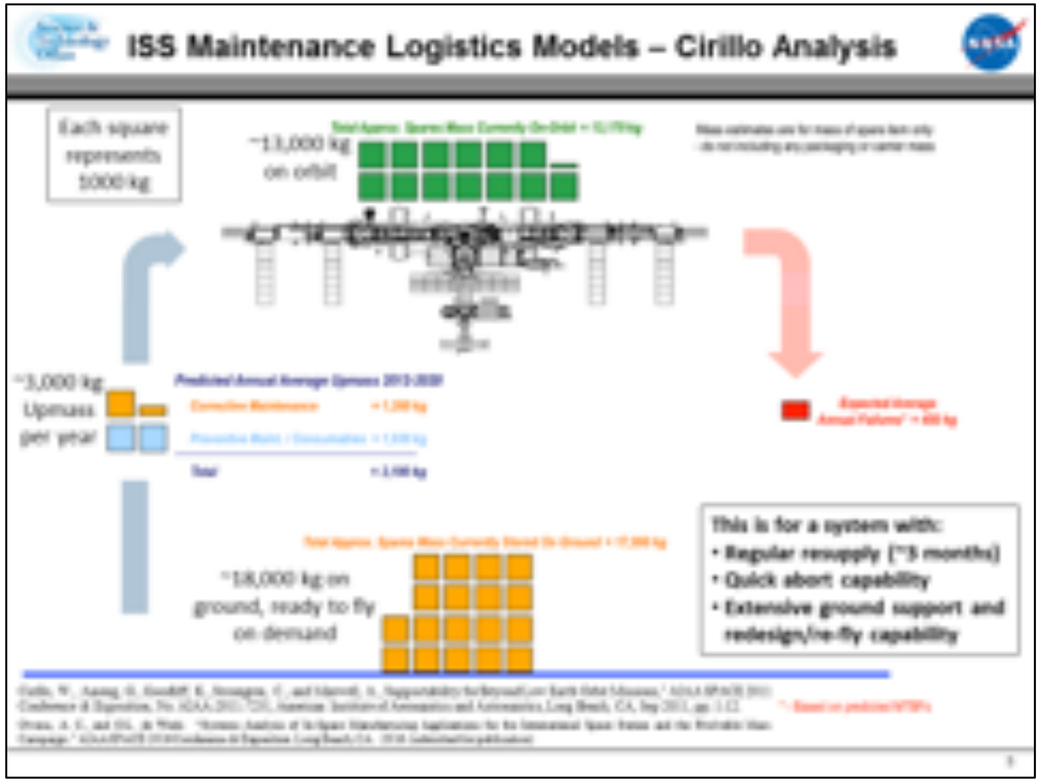
Extensibility to In-space Manufacturing & Planetary Surface Systems
ISS National Lab
Advanced Materials Research
Additive Manufacturing
Robotic Assembly
& Manufacturing - Archinaut
Factories In Space
Gateway & Depot
On-Orbit Servicing, Assembly
& Manufacturing - SPIDER
640 SQ.METERS
Additive Manufacturing
Path to Exploration
Deep Space Habitat and
Martian Surface Operations
Lunar Outpost & Rovers
Lunar Landers
Surface
Manufacturing,
Habitat and Shielding
Construction
ISRU Systems for
Consumable Production
& Storage (CFM)
Extreme
Environments

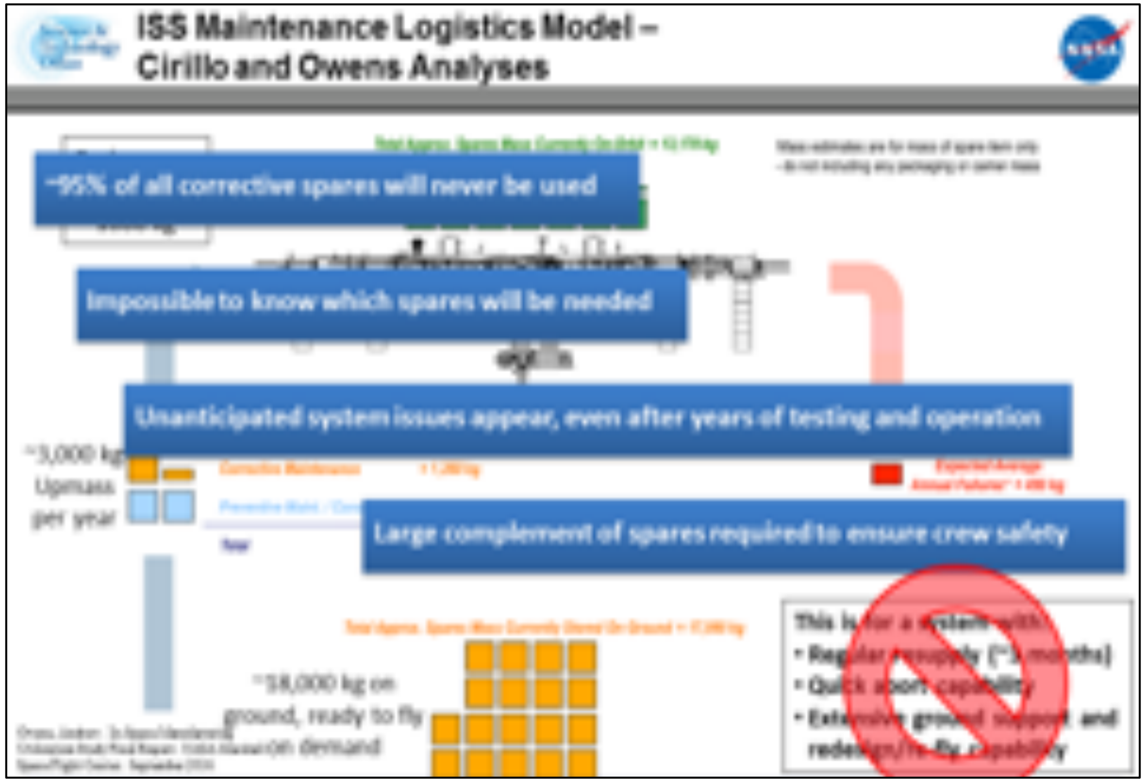
The Case for In-Space Manufacturing and Sustainable Space Exploration

Current maintenance logistics strategies *will not be effective* for deep space exploration

ISM offers the potential to: Repair, Recycle, Reuse and use in-situ resources

- Significantly reduce maintenance/logistics mass requirements
- Enable flexibility to mitigate uncertainty/risks that are not covered by current approaches



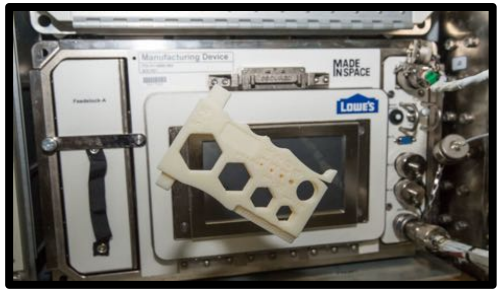


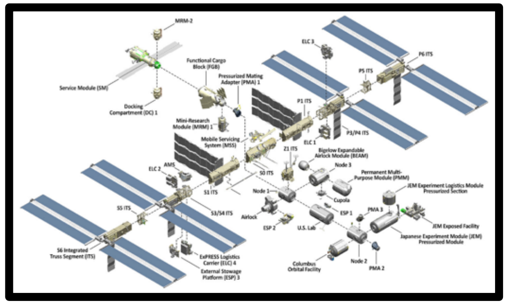
In-Space Manufacturing

20+ years of experience with microgravity 3D-printing and ISS microgravity materials science research

- NASA's Ken Cooper demonstrates microgravity AM (1999)
- ISS 3D-printer projects are state-of-the-art
  - First 3D-printed part in space, NASA/Made In Space (2014)
  - Additive Manufacturing Facility, Made in Space (2016)
  - Zblan optical fiber production, Made in Space (2018)
  - ReFabricator payload, Tethers Unlimited (2019)
- NASA 3D-printed Habitat Challenge (2019)
- NASA FabLab next generation multi-material fabrication laboratory (2022)
- Archinaut - In-space robotic manufacturing and assembly, Made In Space (2022)
- SPIDER - Demonstration of Assembly and Manufacturing in Space, Maxar Technologies (2022)
- On-Orbit Servicing, Assembly and Manufacturing (OSAM)

Sustainable Exploration Links Discovery, Science and Commerce

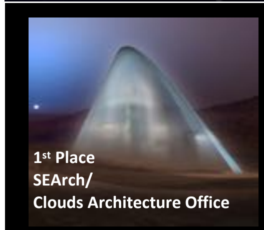



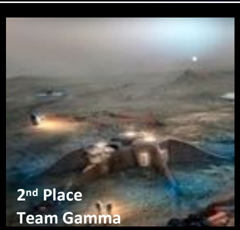



NASA 3D--Printed Habitat Challenge

3D-Printed Habitat Challenge

a NASA Centennial Challenge Program Competition





3DPH Challenge Phase 1: Design
7/2015- 9/2015

Prize Purse: $50,000/$40,000 awarded

(165 entries received, 30 teams were judged)

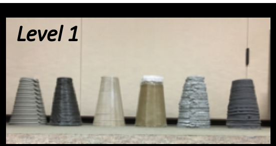
Develop state-of-the-art architectural concepts that take advantage of the unique capabilities offered by 3D printing.

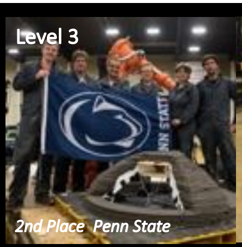
3DPH Challenge Phase 2: Material
6/2016- 5/2017

Prize Purse: $1,100,000/$701,000 awarded

(18 teams registered; 8 teams participated)

Autonomously 3D Print structural components using terrestrial/space based materials and recyclables.





Level 5: Physical Construction Demonstration

3DPH Challenge Phase 3: Build it
11/2017- 5/2019

Prize Purse: $2,000,000/$1,320,000 awarded

(19 teams participated)

Level 4: Virtual Construction (Building Information Model/BIM)

Level 5: Demonstrate an autonomous additive manufacturing system to create a habitat.

Technology Highlights

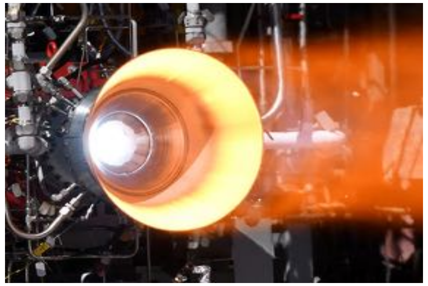
- Demonstration of safe and innovative new **material** compositions for 3D printing pressure vessels on a large scale with application to NASA missions and Earth construction.
- Demonstration of **processes and equipment** for large-scale vertical autonomous construction.
- Diversity/innovation in viable **designs** of realistic planetary Habitats.
- Innovative use of modeling software common to the construction industry as a more **comprehensive design tool** than the software commonly used by the aerospace industry for Additive Manufacturing technologies.
- Demonstration of new **software and control algorithms** for depositing material in a non-two dimensional layer.

Media Engagement:

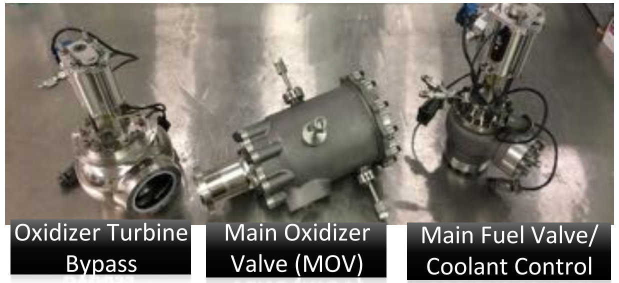
- Phase 3 generated **408** media features resulting in an estimated **113.5 million** viewers.
- The Facebook Live broadcast of the head to head competition had **1,936 views.**
- Media coverage included **CNN, Business Insider, Fox News, and Popular Mechanics.**

NASA Additive Manufacturing of Liquid Rocket Engine Components

- **Hundreds of combustion devices components – injectors, valves, combustion chambers, channel-wall nozzles, and turbo-pumps – have been designed and built using AM and hot-fire tested over the past 10 years**
- **NASA is continuing to advance these technologies on a path towards flight systems**



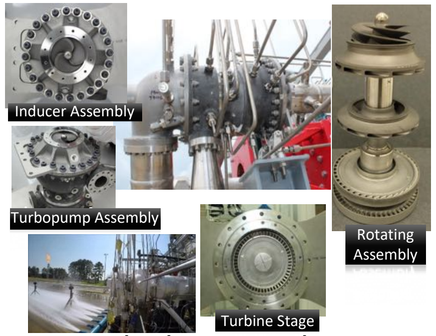
Lox/Hydrogen Testing



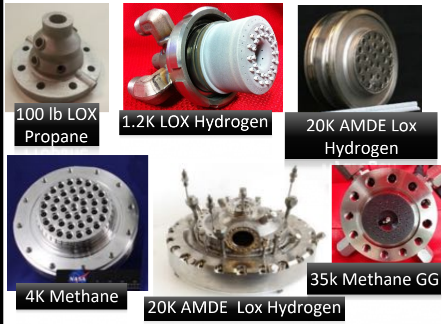
Valve Development

Combustion Chambers

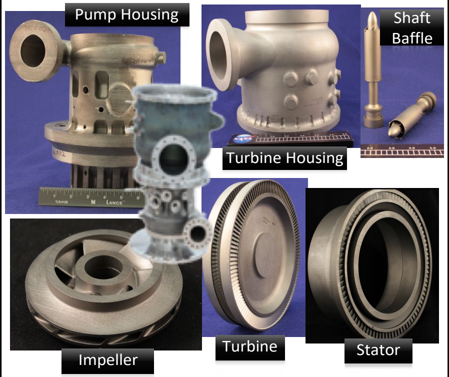
Channel-cooled Nozzles



Fuel Turbopump Development



Injector Development



Liquid Oxygen Turbopump Development

NASA Standards for Additive Manufacturing

- **Additive Manufacturing (AM) is rapidly becoming more pervasive**
  - **Drivers - design innovation, cost and time reduction**
- **There is a critical need to increase NASA's knowledge and understanding of the materials, processes, analysis, inspection and validation methods for AM Parts**
  - **Standardization - development of qualification and certification methodologies**
  - **Property validation, Computational materials, NDE, Process monitoring**
- **The NESC formed a team to explore creation of Agency Standards and Specifications for AM components**
  - **Includes participation from nine NASA centers, and representatives from the FAA, Air Force, Navy and Army**

MEASUREMENT SYSTEM IDENTIFICATION METRIC/SI (ENGLISH) UNITS

National Aeronautics and Space Administration

MSFC-STD-3716
BASELINE
EFFECTIVE DATE: October 18, 2017

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

EM20

MSFC TECHNICAL STANDARD

STANDARD FOR ADDITIVELY MANUFACTURED SPACEFLIGHT HARDWARE BY LASER POWDER BED FUSION IN METALS

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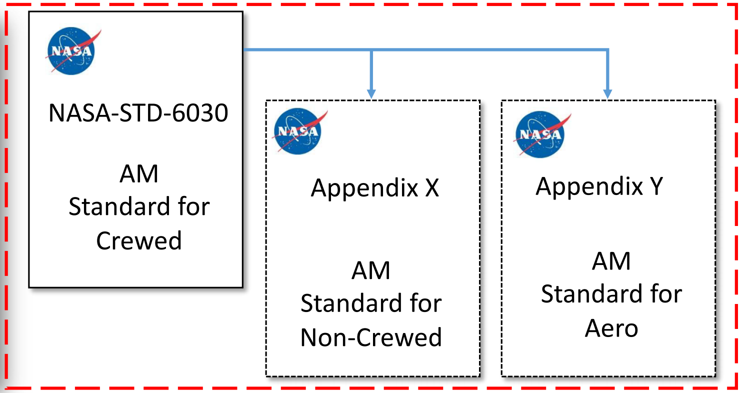

Sustainable Exploration
Links Discovery, Science and Commerce

The object of your mission is to explore the Missouri river…and its communication with the waters of the Pacific ocean…. for the *purposes of commerce.*

Thomas Jefferson, 1803

Acknowledgements

Contributors

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Thank You

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