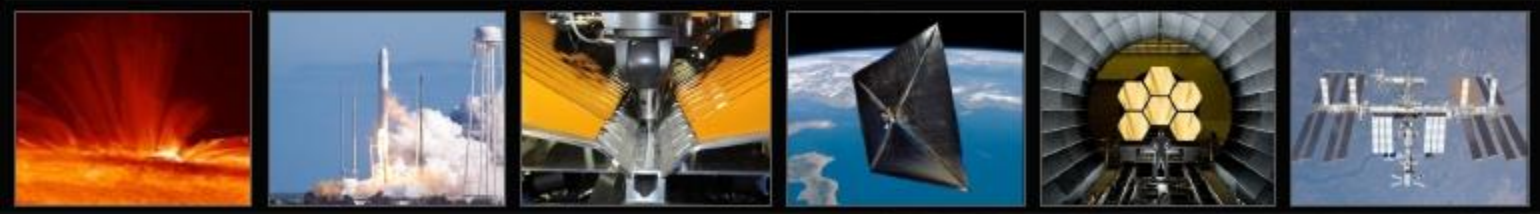
National Aeronautics and Space Administration

marshall

Industry 4.0 : How the New Interaction Between Man and Machine in Smart Factories Will Help Create More Intelligent Products in the Aerospace Industry

Aerospace Innovation Forum 2016



Daniel Schumacher, Ph.D.
Deputy Manager, Science and Technology Office

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.

Introduction to National Additive Manufacturing Innovation

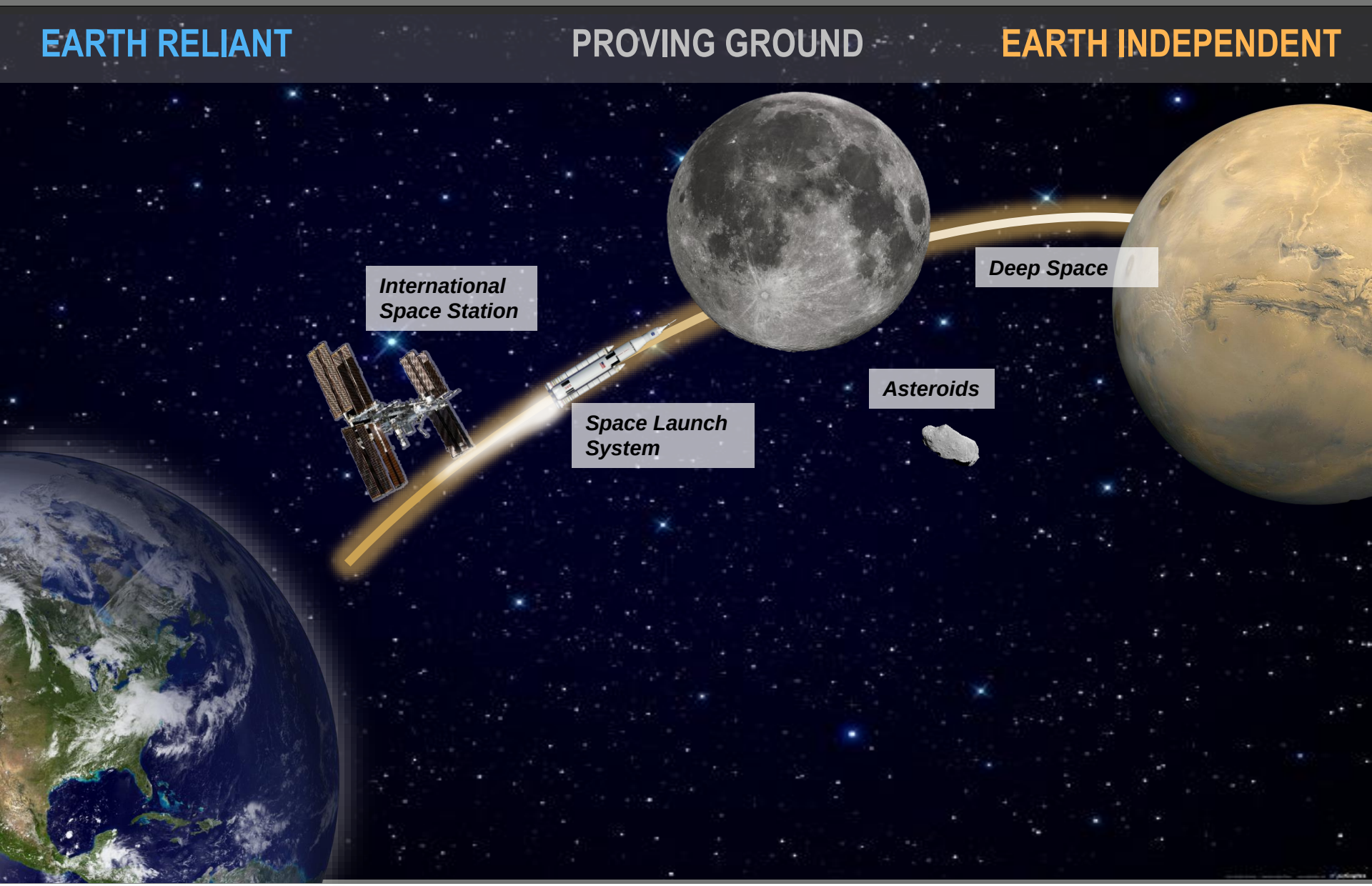
National Maker Faire
June 18-19

National Week of Making
June 17-23

Agenda

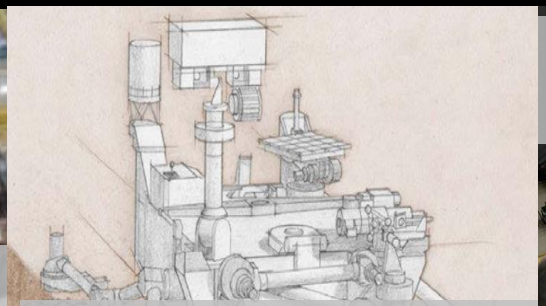
- NASA's Role in Advanced Manufacturing
- In Space Manufacturing Initiative (ISM)
- For Space Manufacturing:
  - Additive Manufacturing of Liquid Rocket Engine Components
  - Additive Manufacturing's Role in the RS-25 Affordability Initiative

Path to Exploration



NASA's Role in Advanced Manufacturing

One of the largest composite cryotanks ever built.



Metallic glass material advancing rovers.

One of the largest robotic friction stir welding systems in the World.

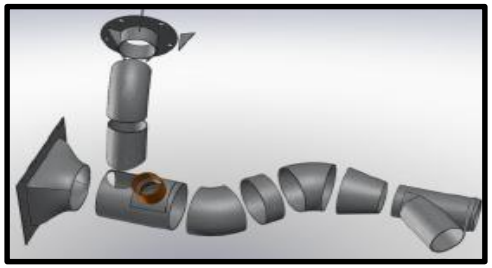
Michoud, 43-acre facility remains one of the biggest manufacturing facilities in existence.

Woven composite materials provide advanced thermal protection.

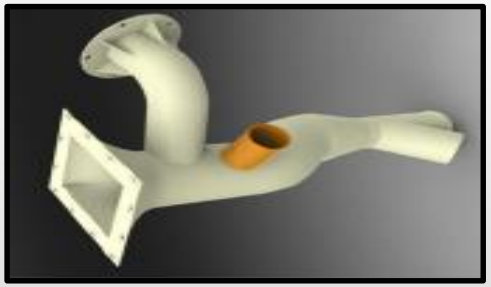
Additive Manufacturing

Why additive manufacturing?

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

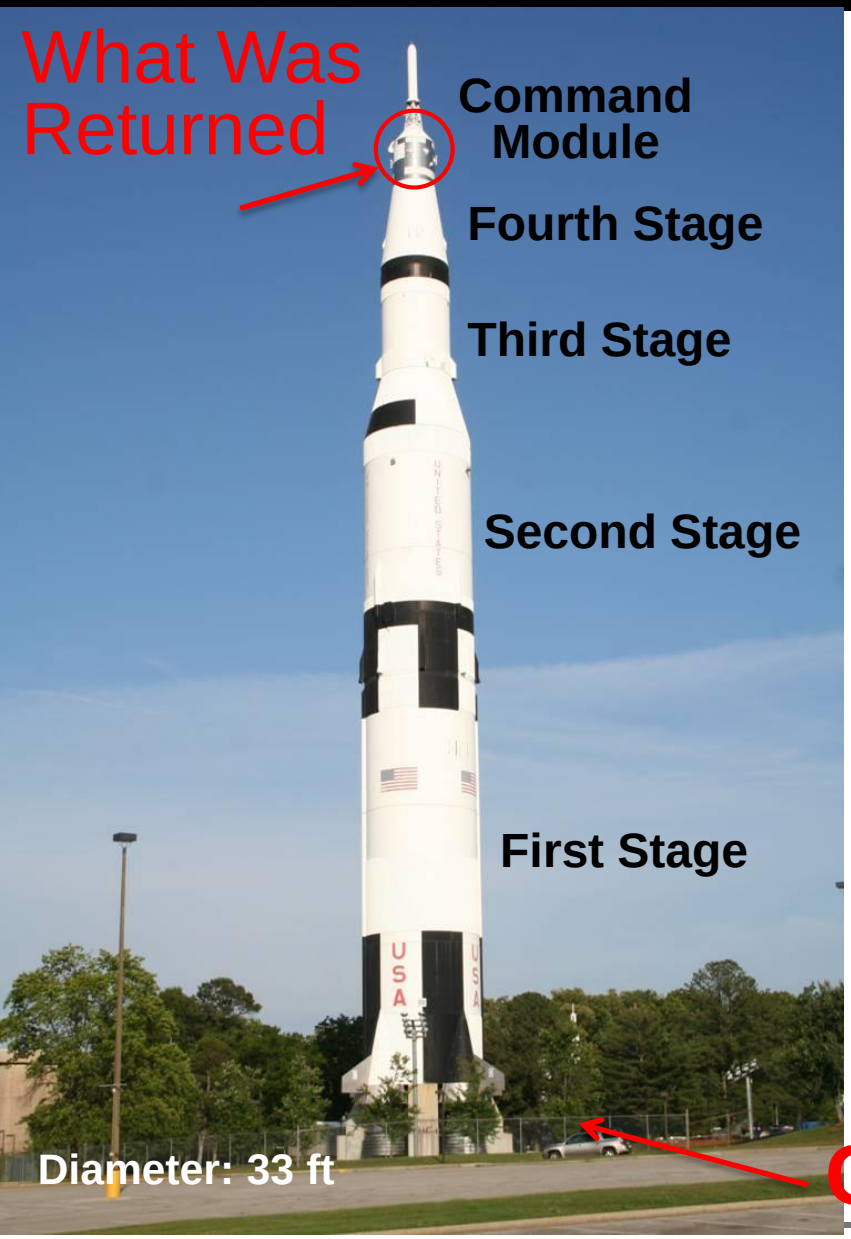


Traditional Part:
19 aluminum parts welded together



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

Saturn V – MASSive Perspective

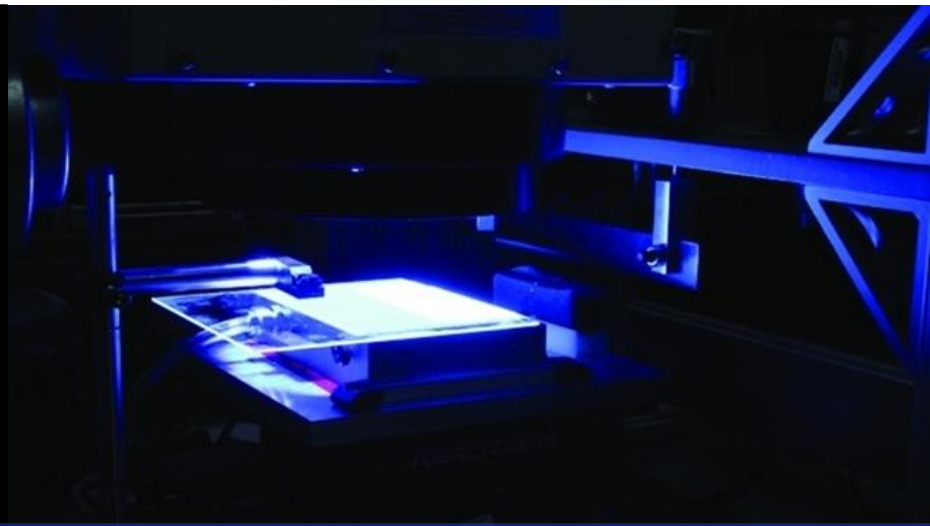


SATURN V

- 6.6M lbs sat on the launch pad.
- But only 12.8K lbs came back.

This is equivalent to taking a road trip in a car and coming back with just the left front wheel's lug nuts!

National Aeronautics and Space Administration



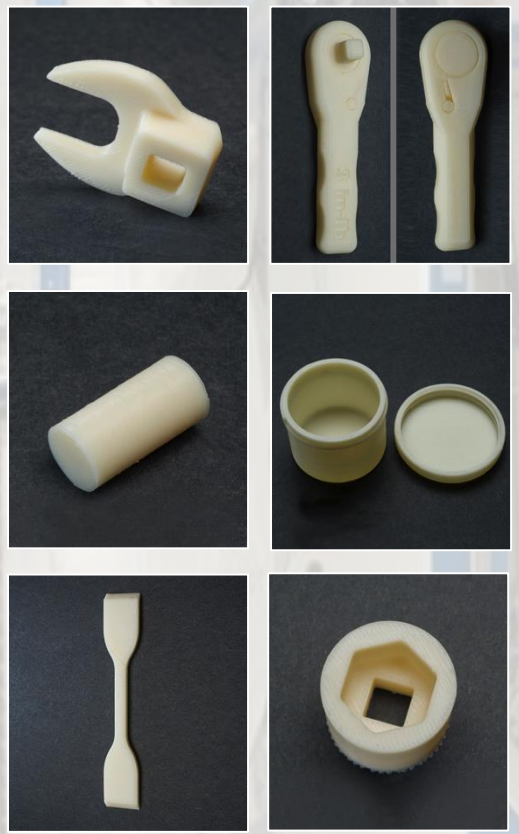
Additive Manufacturing

at Marshall Space Flight Center

In Space Manufacturing Initiative

3D Printing and ISS are Helping NASA Get Parts in Space

Functional Tools

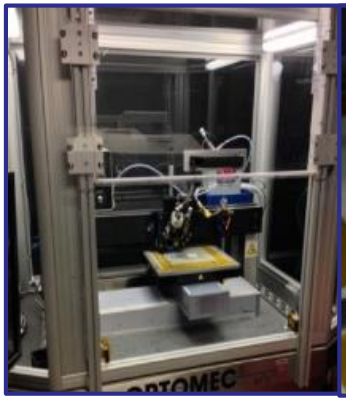


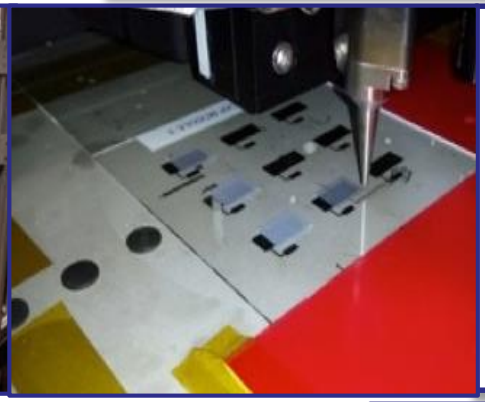
To date, 21 parts have been printed.

In-Space Manufacturing Plans for the Future

In-space Recycler ISS Tech Demonstration Development

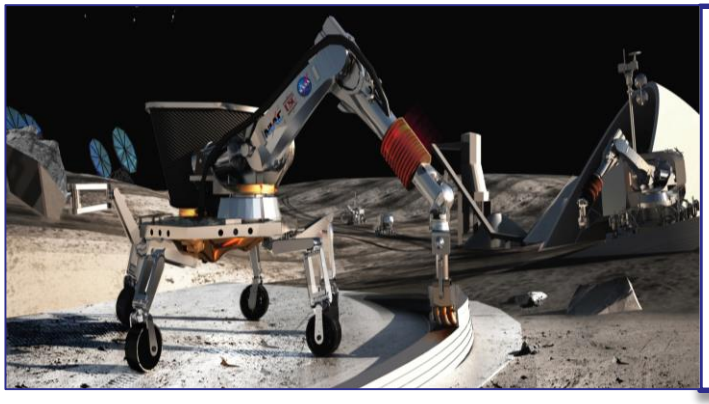
Phase II SBIR was awarded to Tethers Unlimited for a proposed ISS Tech Demo in 2017





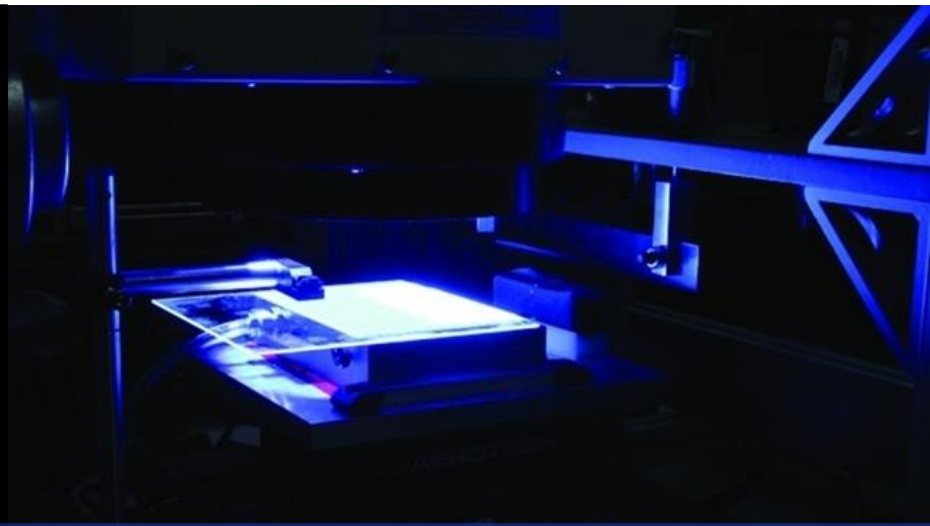
In-space Printable Electronics Technology Development

SBIR with Xerox Palo Alto Research Center (PARC), and NASA Ames Research Center, targeting future ISS Tech Demo.



ACME - Additive Construction by Mobile Emplacement

Joint initiative with the U. S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL) Automated Construction of Expeditionary Structures (ACES) Project

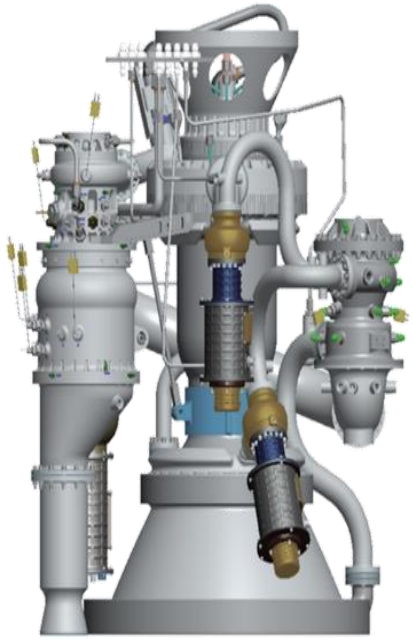


Additive Manufacturing

at Marshall Space Flight Center

Advanced Manufacturing Demonstrator - Liquid Propulsion System and Low-Cost Upper Stage Propulsion Project

Strategic Vision for Future AM Engines



Typical Engine Developments	Prototype Additive Engine
DDT&E Time	
7-10 Years	2-4 Years
Hardware Lead Times	
3-6 Years	6 Months
Prototype Costs	
$20-50Million	$3-5Million

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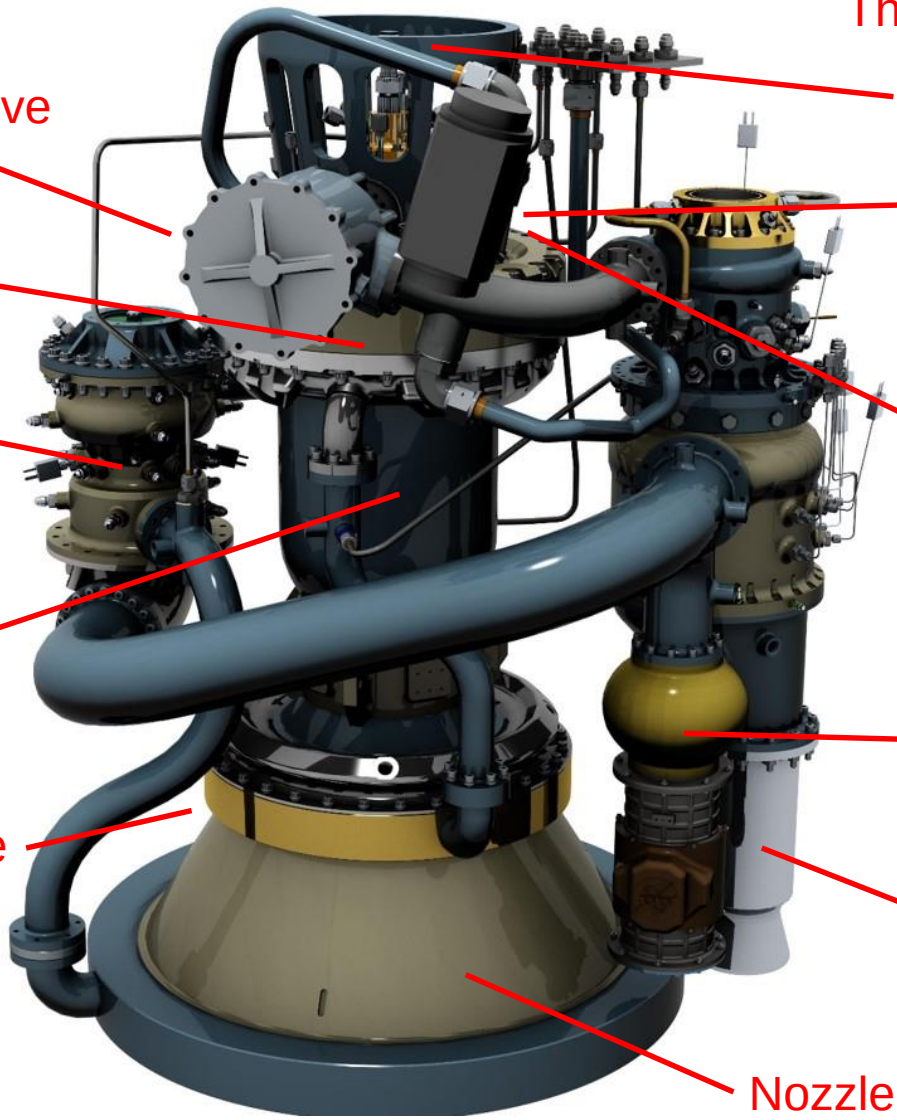
Transferring Material Property Data & Technology to U.S. Industry.

The Result

- **Approximate Part Counts**



Thrust Structure

Main Oxidizer Valve
- 1 vs. 6

Injector
- 6 vs. 255

Fuel Turbo Pump
- 22 vs. 40

Main Combustion Chamber

Chamber Coolant Valve (Hidden)
- 1 vs. 5

Main Fuel Valve (Hidden)
- 1 vs. 5

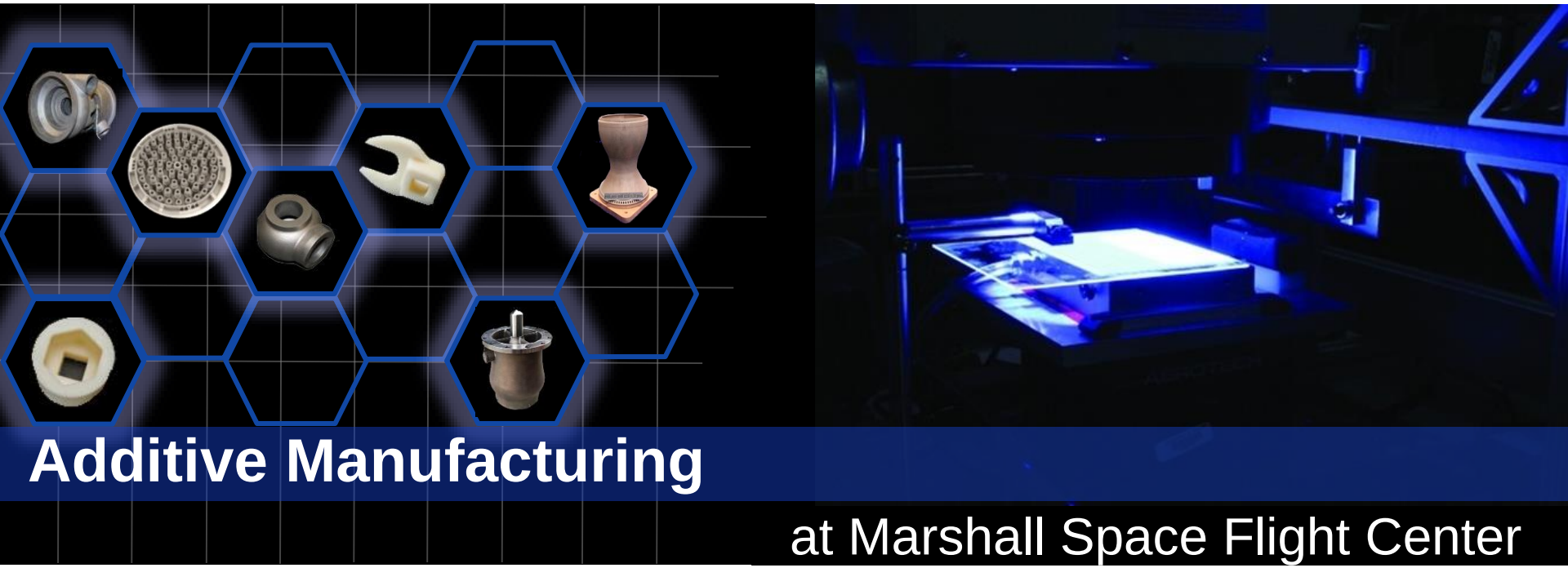
Mixer (Hidden)
- 2 vs. 8

Oxidizer Turbine Bypass Valve
- 1 vs. 5

Turbine Discharge Duct

Nozzle

Note: Part counts examples are for major piece parts and do not include bolts, nuts, washers, etc



Additive Manufacturing

at Marshall Space Flight Center

RS-25 Affordability Initiative – Additive Manufacturing's Increasing Role

RS-25 Affordability Strategy

33% Reduction in Engine Cost

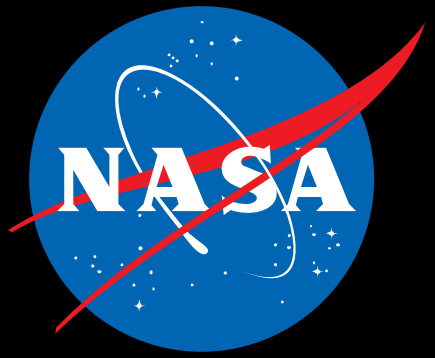
>700 Welds Eliminated
>700 Parts Eliminated

35 AM Opportunities Identified for RS-25

Working With AEROJET ROCKETDYNE

What is the future?
What role will you play?

“It is difficult to say what is impossible, for the dream of yesterday is the hope of today, and the reality of tomorrow.”
Robert H. Goddard



www.nasa.gov