National Aeronautics and Space Administration

# Partnerships to advance next generation manufacturing capabilities in support of NASA's exploration goals

Marshall Space Flight Center

Mallory James

AST Technical Management, MSFC Partnerships & Opportunities Development Office

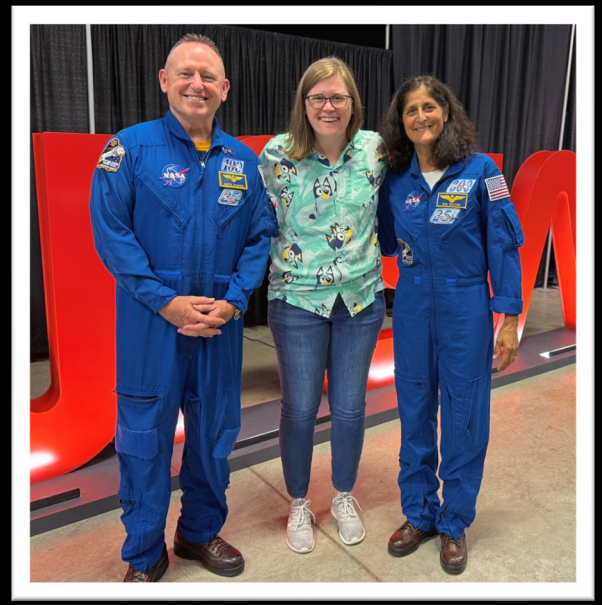
June 2026


WELCOME HOME
ARTEMIS II

# About Me

National Aeronautics and Space Administration

- B.S. in Industrial and Systems Engineering from Auburn University, 2013
- M.S. in Human Factors in Aeronautics from Florida Institute of Technology, 2017
- 10 years in various military systems engineering and manufacturing roles supporting acquisition of aviation and weapons systems for both the Army and Navy
  - Highlights of systems supported: oxygen systems, night vision goggles, ejection seats, torpedoes, rotor and fixed wing platform integration, turbine engines
  - Systems engineering lifecycle reviews, manufacturing readiness, structural and environmental testing, integration testing, airworthiness
- Additive manufacturing certification & strategy 2021-2025 at NASA Marshall Space Flight Center including detail to Director's Office for one year in 2023
- Partnerships and Opportunities Development Office, summer 2025-present
  - Partnerships and Formulation – new partnership/project formulation leveraging Marshall capabilities and expertise
- Wife and mom to two kiddos and a rescue pup named Blueman
  - We enjoy baseball, swimming, baking, snacking



# About my coauthors

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Chris Protz - Materials and Processes Laboratory - Advanced Manufacturing Technical Lead

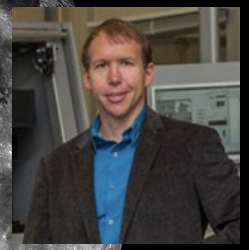
- Coordinates the evaluation, development, and integration of advanced and in-space manufacturing technologies and capabilities for NASA and partner programs and projects
- Experienced in design, analysis, conventional and additive manufacturing and testing of liquid rocket engine components and spacecraft and vehicle systems
- Education: Bachelors, Masters, and PhD in Aerospace Systems from Massachusetts Institute of Technology

Brady Kimbrel - Additive Manufacturing Team Lead

- Manages day-to-day operations of MSFC Additive Manufacturing Lab and leads team of AM SMEs conducting in-house development and AM support for NASA programs
- 10 years of experience working with metallic and polymer AM processes for spaceflight applications
- Education: Bachelors in Aerospace Engineering from University of Alabama in Huntsville

Jennifer Jones - In-Space Manufacturing (ISM) – Portfolio Manager

- Manages ISM's four focus areas: welding/additive, electronics, recycling, and verification technologies
- Provided materials selection for space environment support for HLS, SLS, and Frozen Return of Orbital Samples to Earth projects; Holds Project Management Professional certification
- Education: Bachelors in Chemistry from Cornell University and PhD in Chemistry from Northwestern University



Brian West - Valves, Actuators, Lines, Ducts Manager – Space Launch System, Liquid Engines Office

- Manages production and delivery of Valves, Lines, Ducts, and Actuator hardware for the RS25 Program
- Experienced in flight hardware production, testing, and additive manufacturing certification methodology development
- Education: Bachelors in Mechanical Engineering from University of South Florida and Masters in Industrial and Systems Engineering from the University of Alabama in Huntsville

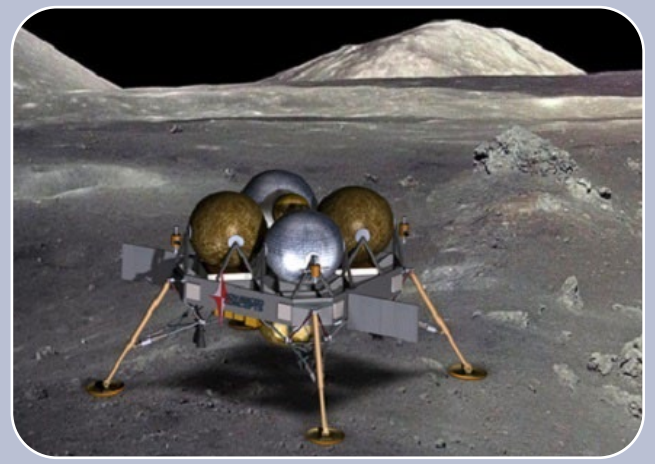
# MARSHALL

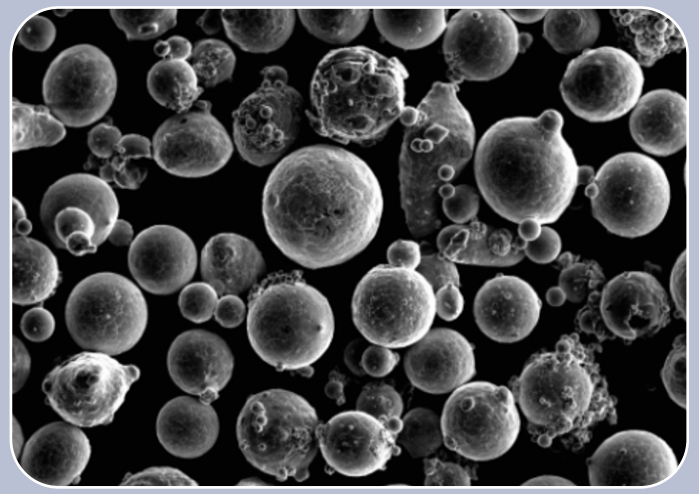
**3rd Largest NASA Center**

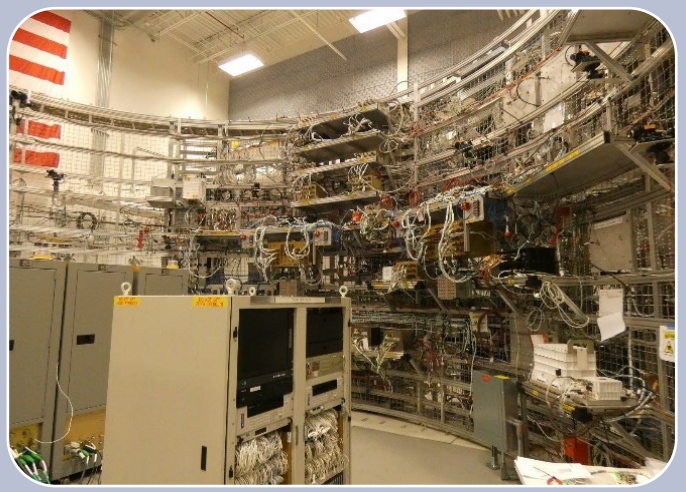
**Nearly 7,000 Employees**

**$5 Billion Budget**

# ENGINEERING







## Advanced Concepts Office

Ideas → Concept → Reality through innovative thinking and proven principles

Rapid turnaround concept definition studies

Custom-tailored solutions for individual customers

## Materials & Processes Laboratory

Advanced and In-Space Manufacturing driven by expertise in Metals, Non-metals, Additive Manufacturing Qualification

Materials Science, Metallurgy, Damage Tolerance, Non-Destructive Evaluation, Testing

Infrastructure and Consultation aligned for Manufacturing Partnerships

## Space Systems Department

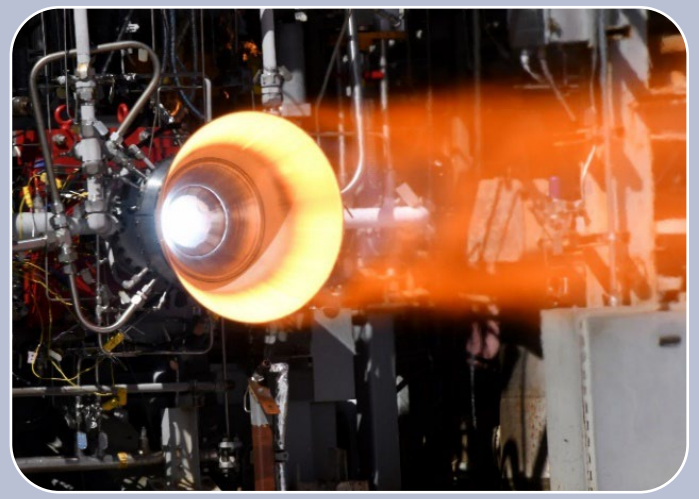
Spacecraft, Payloads, Avionics, Software, Cameras, Printed Electronics

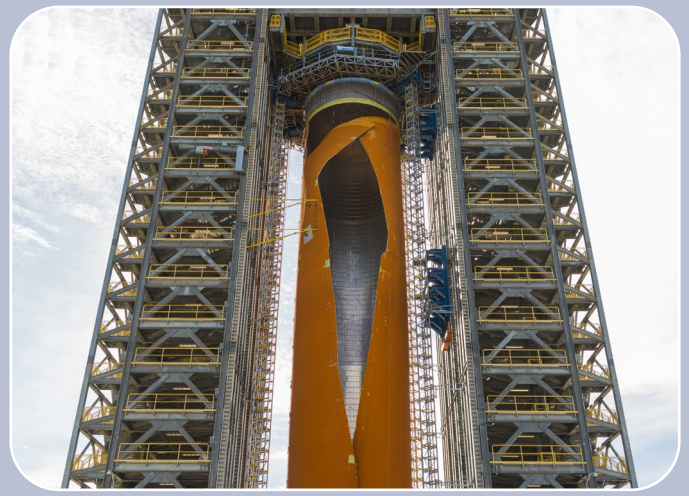
Advanced Environmental Control & Life Support System

Component design, integration, testing

SE&I including Avionics Integration for Human Space Flight, Science Missions, and Exploration Initiatives

# ENGINEERING





## Spacecraft & Vehicle Systems Development Department

Systems Engineering & Integration for Spacecraft & Launch Vehicle Systems

Structural, Integrated Loads, Aerodynamics & Thermal Design & Analysis

Guidance, Navigation & Control and Integrated Performance

Terrestrial & Space Environments

## Propulsion Systems Department

Design & Analysis for Liquid, Solid, & Nuclear Thermal/Electric Propulsion

Propellant Management - long duration storage & transfer for cryogenic and storable prop

Technology development - electric pumps, low leakage valves, integrated reaction control systems

Propulsion component design & development including extensive test capabilities

## Test Laboratory

Propulsion, Environmental, Experimental Fluid Dynamics, Structural Strength, and Structural Dynamic Testing

Space Flight Hardware Testing and Anomaly Resolution; Research and Technology Development Testing

Facilities aligned for both Agency and Partner Support

# NASA Manufacturing Is...

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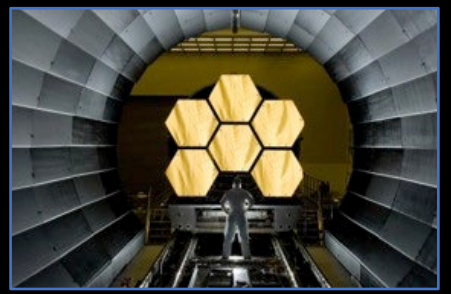
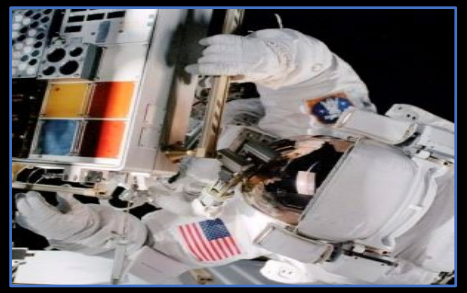

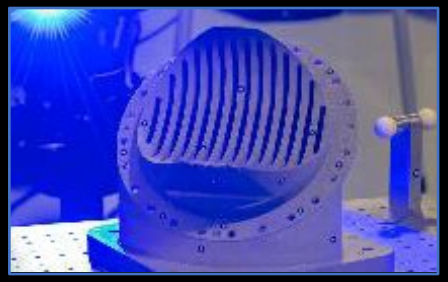
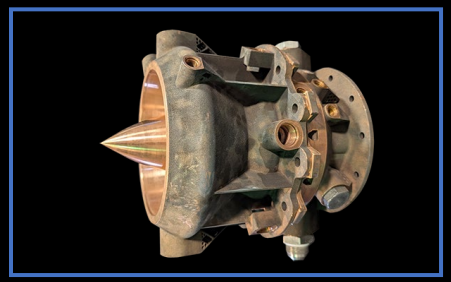


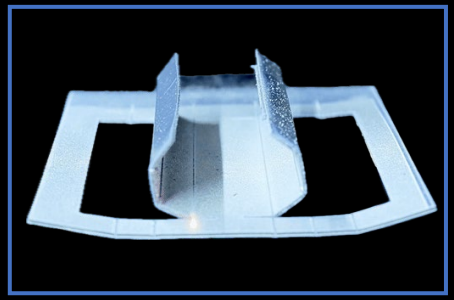

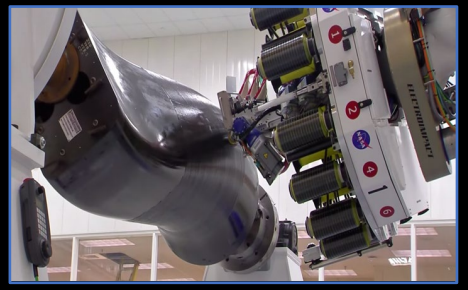



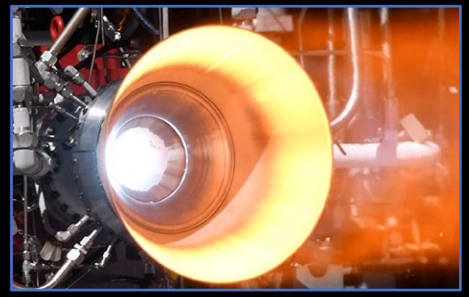

# Additive Manufacturing at NASA

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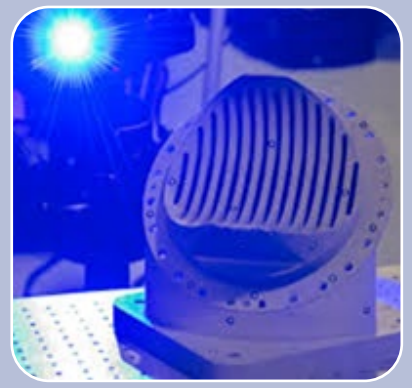
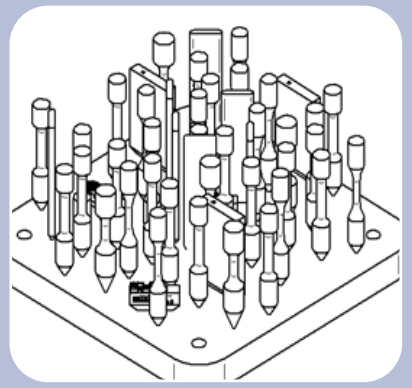
- Drive AM technological innovations & maturity
- Provide framework for AM hardware certification for human-rated spaceflight
- Technical and risk cultures vary by component criticality & mission portfolios
  - Standards establish a common language & risk communication tools
  - Requirements are tailorable
- Share knowledge and data in pursuit of a well-informed AM user community
  - ***A rising tide lifts all boats***
- Experience in numerous AM technologies
  - Metallic: Laser Powder Bed Fusion, Directed Energy Deposition, Wire Arc AM, Liquid Droplet
  - Polymers: Fused Deposition Modeling, Stereolithography
  - Ceramics: Stereolithography





### Innovate

Collaborative effort between NASA and Aerojet Rocketdyne to 3D print RS-25 pogo accumulator resulted in 78% reduction in welds, 35% cost reduction, and 80% production time savings. The team went on to leverage AM for more than 30 other components on the new engine.

### Qualify

NASA-STD-6030 and NASA-STD-6033 provide the requirements framework for material process qualification and component certification of AM spaceflight hardware. NASA has also supported AM research & development of custom alloys including GRCop-42 and HR-1.

### Certify

Beyond AM material and process qualification, NASA has immense expertise in system qualification and certification testing.

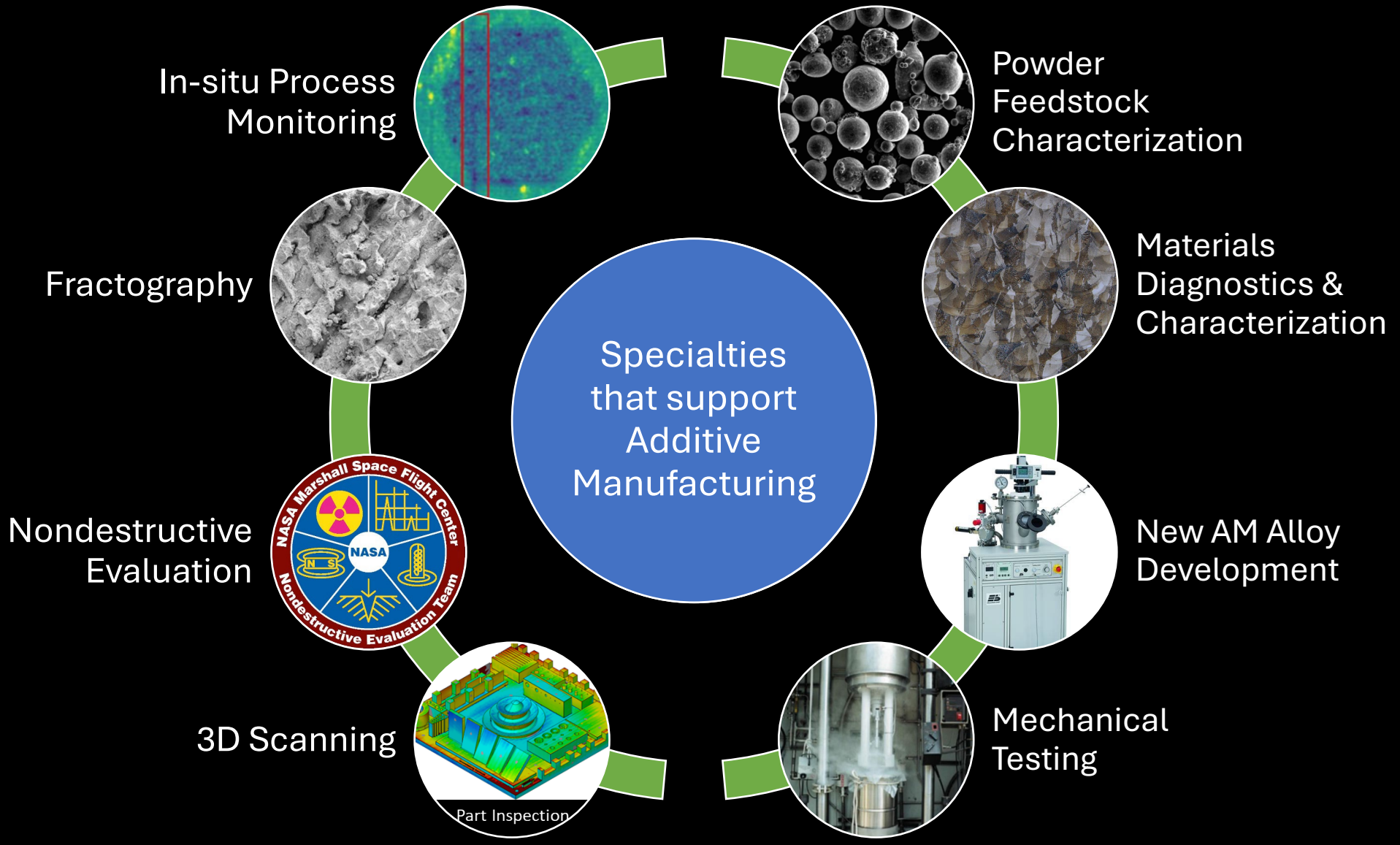
Requirements are tailorable in accordance with mission and part classification to meet each project's unique risk posture.

### Institutionalize

Programs like SLS's RS-25 provided *fleet leader* success for a systematic and institutional approach to leveraging AM to its fullest potential. NASA's Artemis portfolio includes many other AM applications, tailored appropriately to unique AM applications and risk postures.

# Additive Takes a Village

National Aeronautics and Space Administration



# Space Technology Research Institute

## *Institute for Model-Based Qualification & Certification of Additive Manufacturing*

National Aeronautics and Space Administration

IMQCAM

INSTITUTE FOR MODEL-BASED QUALIFICATION & CERTIFICATION OF ADDITIVE MANUFACTURING | NASA STRI

Co-Is: Tony Rollett, Carnegie Mellon University & Somnath Ghosh, Johns Hopkins University

**Vision**: Deliver a Digital Twin platform comprising a powerful set of integrated computational models and simulation tools that can be used with confidence by NASA researchers and practitioners for the qualification and certification of metal AM processes and products.

**Major Focus Areas:**

- Process Modeling
- Multiscale Modeling & Life Prediction
- Digital Twin Assisted Qualification & Certification
- Data & Software Integration

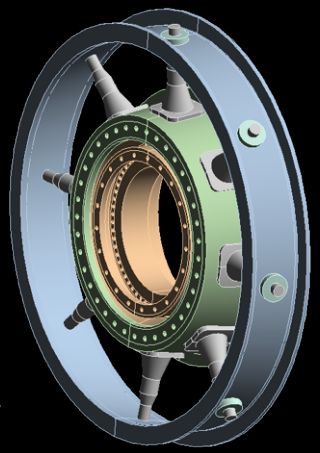
**Major Partner Institutions**:

- Carnegie Mellon University
- Johns Hopkins University
- JHU-Applied Physics Laboratory
- Vanderbilt University
- University of Texas-San Antonio
- Southwest Research Institute
- University of Virginia
- Pratt & Whitney
- Case Western Reserve University

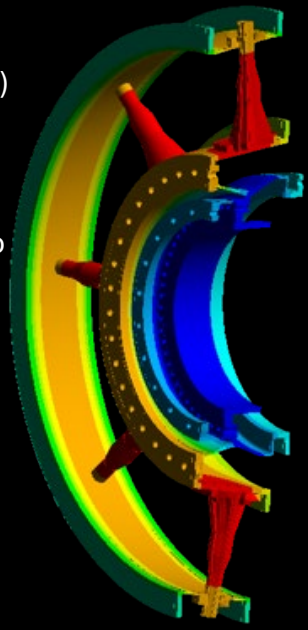
Group photograph from the IMQCAM Annual Meeting August 7-8 at JHU. Photo credit: CMU

# *Progress Highlight*

## Challenge Part to Exercise Model-Based AM Qualification & Certification Approach



1. ***Location-specific properties.*** Predict local, path-dependent properties during design phase. Not feasible using current methods make and test methods. (Coupons and Components)
2. **Component material design curves.** Apply location-specific component properties to location-specific component design and lifing process **OR** establish finite pedigrees (sub-sets of total material capabilities) that can be used for pragmatic discretization of part volume.
3. **Component geometry design.** Optimization of component geometry to enable manufacturability and target application capabilities relative to defined failure modes.
4. ***Process definition.*** Define processing conditions (target and tolerances) that will produce the required material structure and defect characteristics that will produce required location-specific properties.
5. ***Qualification of additive process.*** Define process sensitivity and associated process parameter controls and monitoring requirements, so process performance and repeatability can be measured over the component applicable range(s).
6. ***Part classification.*** Assess and define volume element distribution of application stresses throughout final part and assess and define volume element distribution of process defect or microstructure risks, which superimposed provide for part level PoF risks.
7. ***Certification test plan.*** Establish test material volumes/locations that provide required capability information to support process control and property validation.



# L3Harris-Aerojet Rocketdyne Partnership

Supporting Human-Rated Additive Manufacturing Applications For RS-25

National Aeronautics and Space Administration

## ACTIVE INDUSTRY PARTNERS

### Aerojet Rocketdyne

Cost-sharing development partner with NASA

Human-rated propulsion applications
Large-scale multi-laser LPBF

### RPM Innovations

Cost-sharing development partner with NASA and AR

LP-DED qualification methodology
RS-25 nozzle application

## 10+ YEARS OF ADDITIVE MANUFACTURING DEVELOPMENT

### Process & Qualification

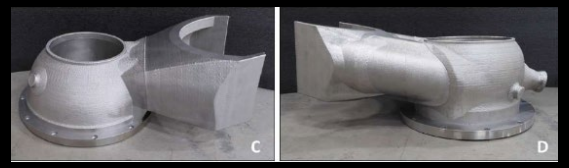
- Developed and characterized multiple AM platforms
- Established L-PBF qualification methodologies
- Supported transition of AM into propulsion applications

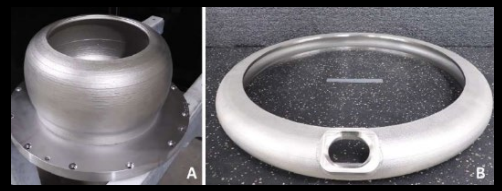
### Systems & Materials

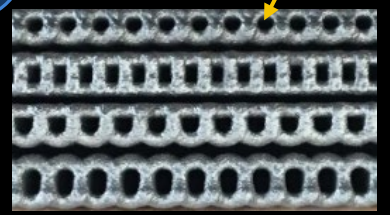
- GE Concept Laser M1 / M2
- Xline 1000R / 2000R
- EOS M100 / M290
- Inconel 625 / 718
- GRCop-42 / GRCop-84
- JBK75 and NASA HR-2

### Standards & Program Impact

- Developed MSFC-STD-3716
- Developed MSFC-SPEC-3717
- Formed foundation for NASA-STD-6030
- Advanced AM requirements for spaceflight systems



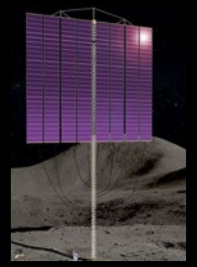



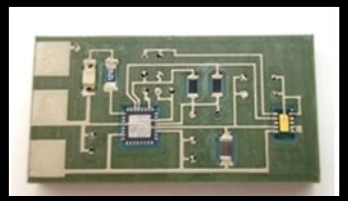
**Program Impact:** Industry partnerships are advancing large-scale AM processes, qualification methods, and standards needed for RS-25 human-rated propulsion applications.

# In-Space Manufacturing Portfolio

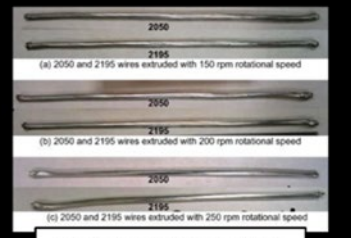
National Aeronautics and Space Administration

| Focus Area | Technology Development | Applications |
|---|---|---|
| Welding/ Additive | Laser Beam Welding<br>High resolution metal additive manufacturing | Critical Repairs and Joining<br>Spare parts<br>Storage Tanks/Tall Lunar Tower/Large Infrastructure |
| Electronics | Additive manufacturing of PCBs and sensors<br>Material properties in space<br>Electronics printers | Microelectronics and Sensors<br>Semiconductors<br>Energy/Power |
| Recycling | Inventory of feedstock materials<br>Relevant processes<br>Needed applications | Polymers/Metals/Composites<br>Outfitting<br>Radiation or Dust Protection |
| Verification Technologies | Non-Destructive Evaluation<br>In-Situ Process Monitoring<br>Tailored certifications | Inspection and certification for non-critical parts and repairs<br>Inspection and certification for critical parts and repairs |

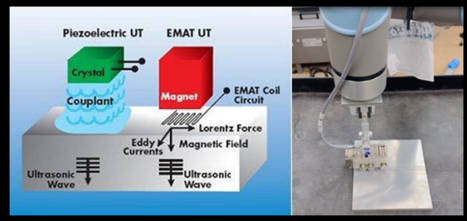




Aluminum Chips




Friction Extruded Wire



# Novel Orbital and Moon Manufacturing, Materials, and Mass-efficient Design (NOM4D)

National Aeronautics and Space Administration

**Goal**: To develop and demonstrate a potential mode of non-contact metals forming via laser applicable to in-space manufacturing

**Collaborators**:

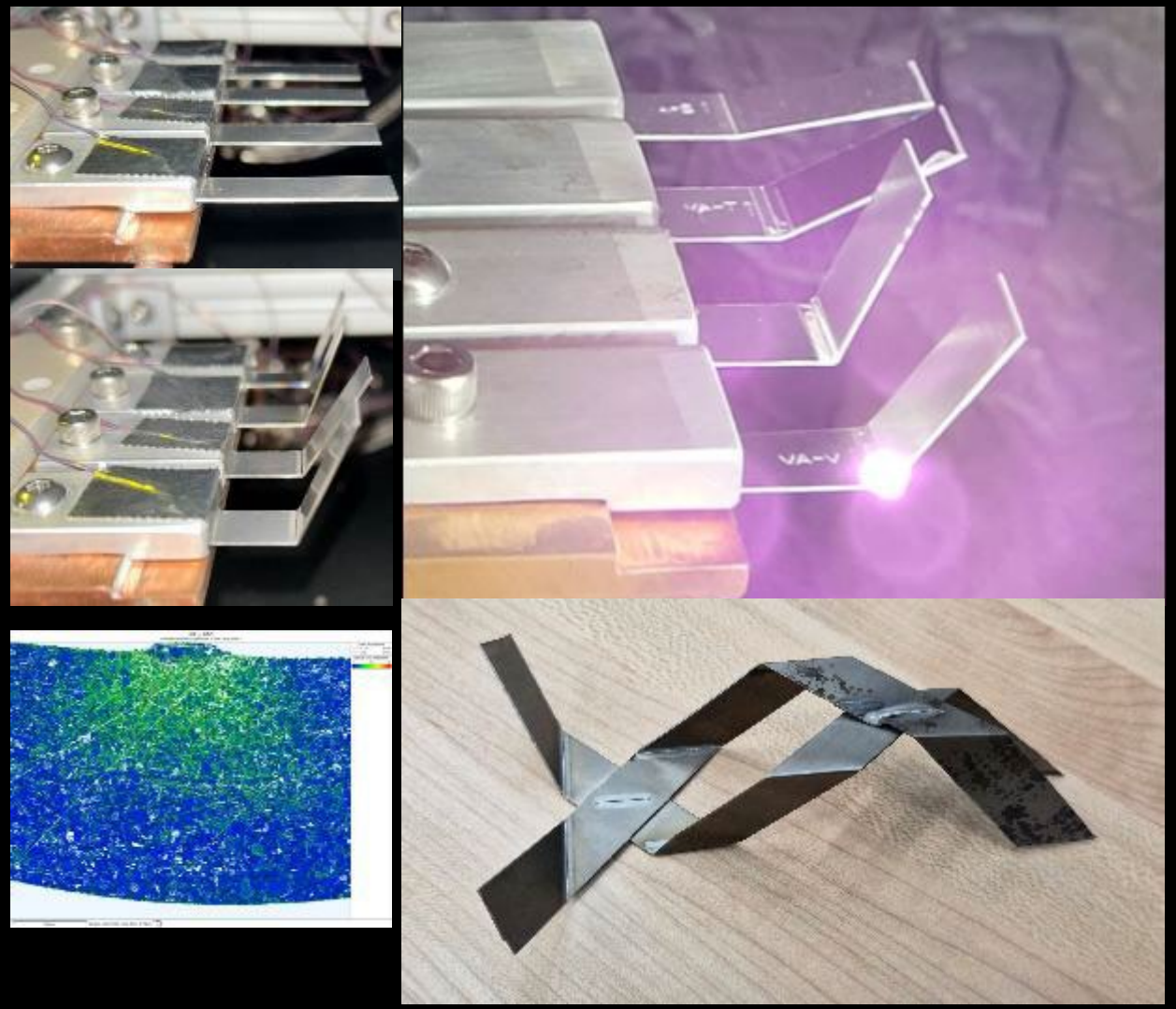
- Defense Advanced Research Projects Agency (DARPA), University of Florida
- Started through DARPA NOM4D and continued with a Collaborative Agreement Notice (CAN) between MSFC and the University of Florida

**Outcomes to-date:**

- Method demonstrated on aluminum, titanium, and stainless steel in ambient atmosphere and vacuum
- Processing in Thermal Vacuum (TVAC) demonstrated method is robust across temperature ranges
- Test coupons characterized
- Examined capability to form and weld with one laser unit

**Next Steps:**

- Mechanical Testing
- Scale up (centimeters to meters)
- Investigation into more complex geometries



Top: Various images of the laser forming process
Bottom Left: EBSD imaging highlighting strain developed during forming
Bottom Right: Demonstration truss sample illustrating bend and weld combinations

# WHY DOES NASA PARTNER?

1

Advance Exploration & Innovation – Drive Moon-to-Mars missions, cutting-edge research, and new technologies.

2

Strengthen U.S. Leadership – Boost the space economy, commercialize innovations, and enhance competitiveness.

3

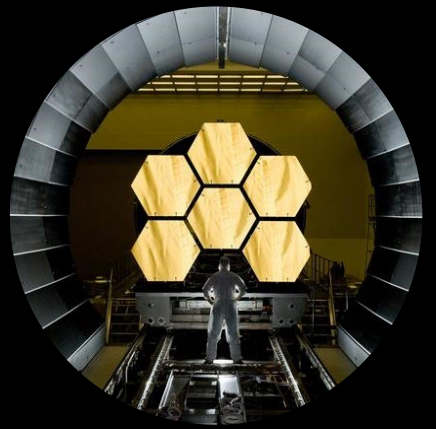
Foster Global Collaboration – Build international alliances for space exploration and scientific discovery.

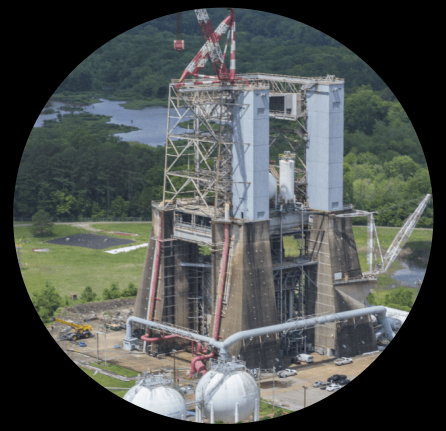
4

Inspire & Educate – Engage the public, expand STEM outreach, and develop future talent.

5

Optimize NASA's Resources – Maximize facilities, expertise, and efficiency through strategic partnerships.





# Humanity's Return to the Moon and on to Mars

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