SPACE INNOVATIONS | SMART BUSINESS

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SPACE COMMERCE CONFERENCE AND EXPOSITION

DECEMBER 5–7, 2017

George R. Brown Convention Center • Houston, TX

National Aeronautics and Space Administration
Marshall Space Flight Center

Additive Manufacturing at NASA/MSFC

Transforming Design & Manufacturing

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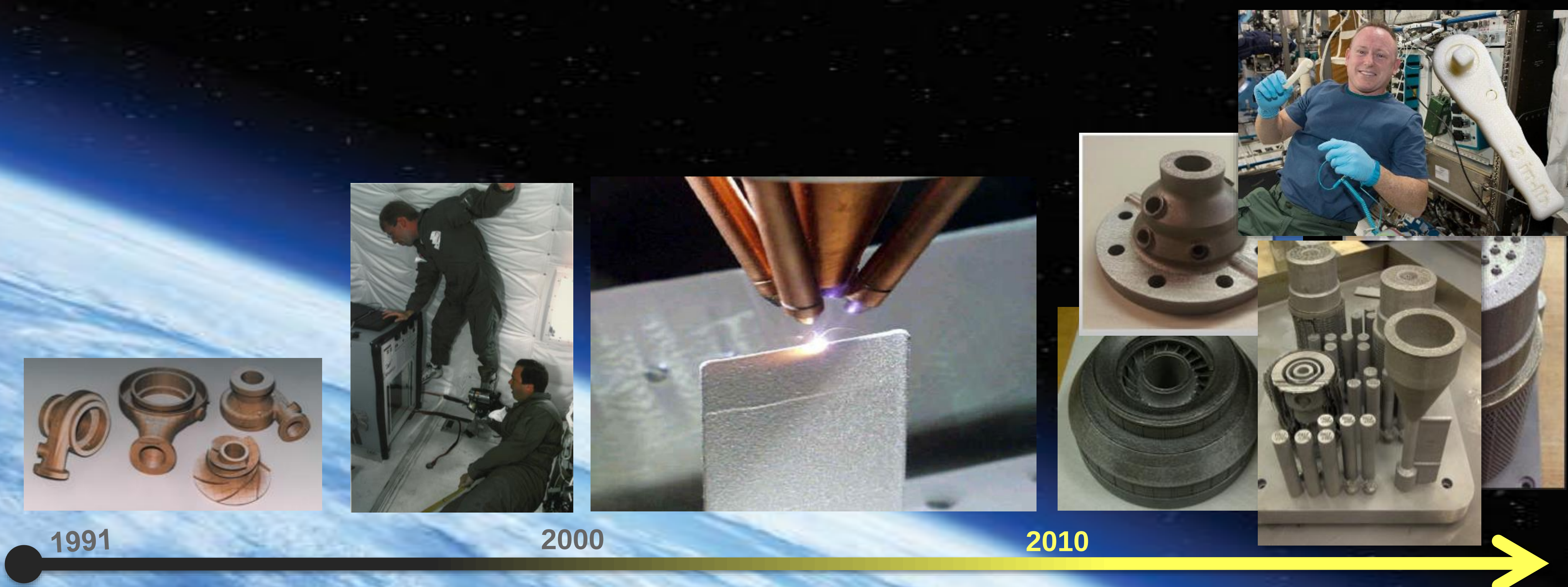
NASA / MSFC

Agenda

- Our History in AM
- Our AM Efforts
  - Manufacturing “In Space”
  - Manufacturing “For Space”
- AM Developments and Goals
- Hybrid AM Developmental Efforts
  (Collaboration with DMG MORI)

Additive Manufacturing History at MSFC

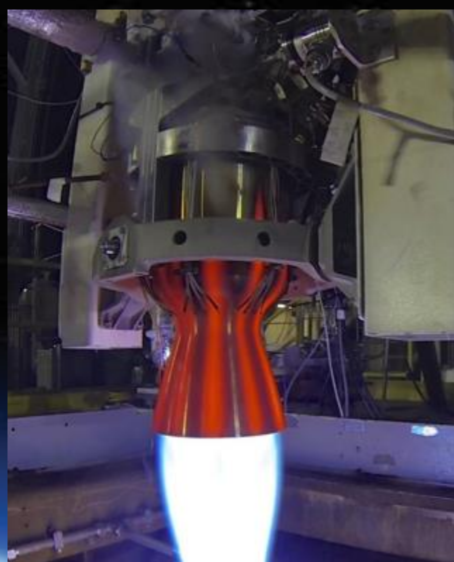
- Extensive experience in Additive Mfg. (AM) design & process development
- Experimented with over 30 AM technologies/systems in the past 26 years
- Capital investments in Powder Bed Fusion hardware, engineering, facilities and testing ($56M in the past 4 years).
- Have the largest commercially available PBF system in Metallic and the largest commercially available polymer AM system



Additive Manufacturing at MSFC

Objectives: **To develop, demonstrate and evolve Additive Manufacturing as a key component of an integrated engineering solution and risk reduction for affordable manufacturing for space transportation systems, and manufacturing in reduced-gravity environments.**

For-Space

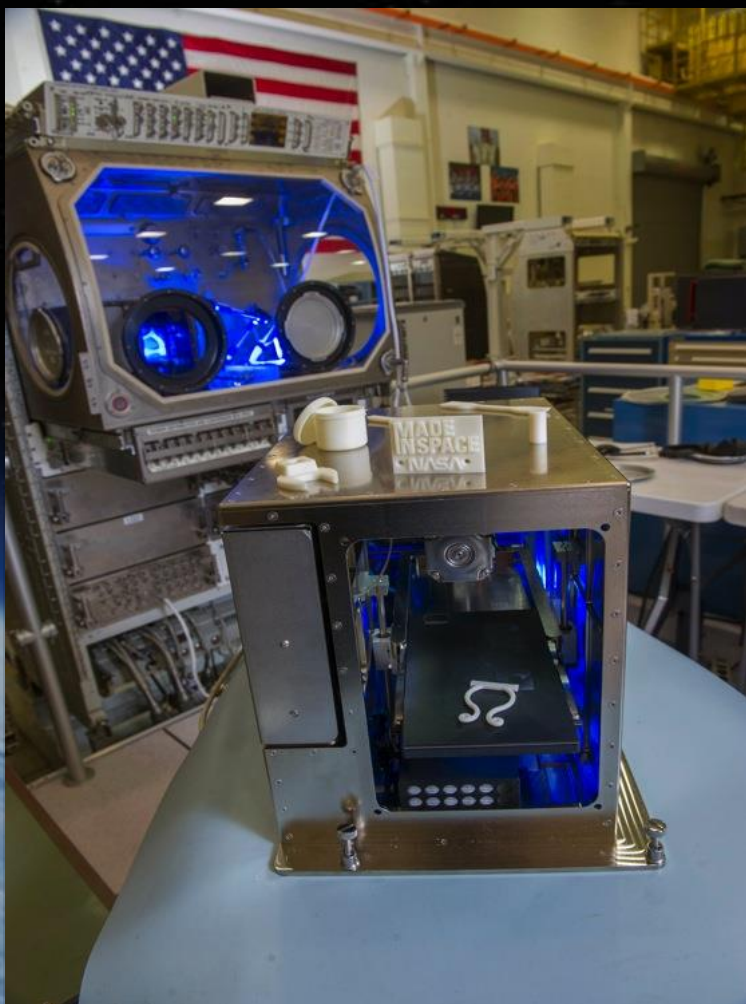


In-Space

AM Manufacturing "IN-Space"

Why is it important?

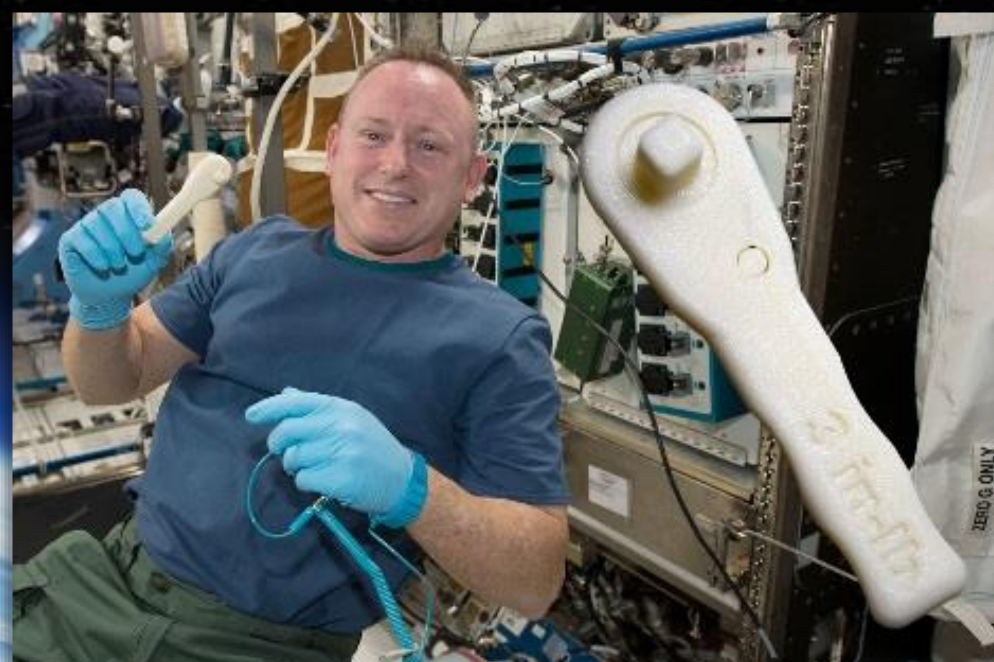
AM is a critical technology for deep space explorations, part replacements, tools and habitats.



3D Print Flight Unit with the MSG Engineering Unit in the background

<u>3D Print Technology Demonstration</u>

- First manufacturing capability in Space (International Space Station)
- Presently have two 3D printers on Space Station and two more are in works. One of which is a 3D printer and recycler (all in one).



AM Manufacturing “For Space”

NASA MSFC is looking to Additive Mfg. and innovative designs to reduce manufacturing cost and schedule and help affordability of access to Space.

Major Efforts Include:

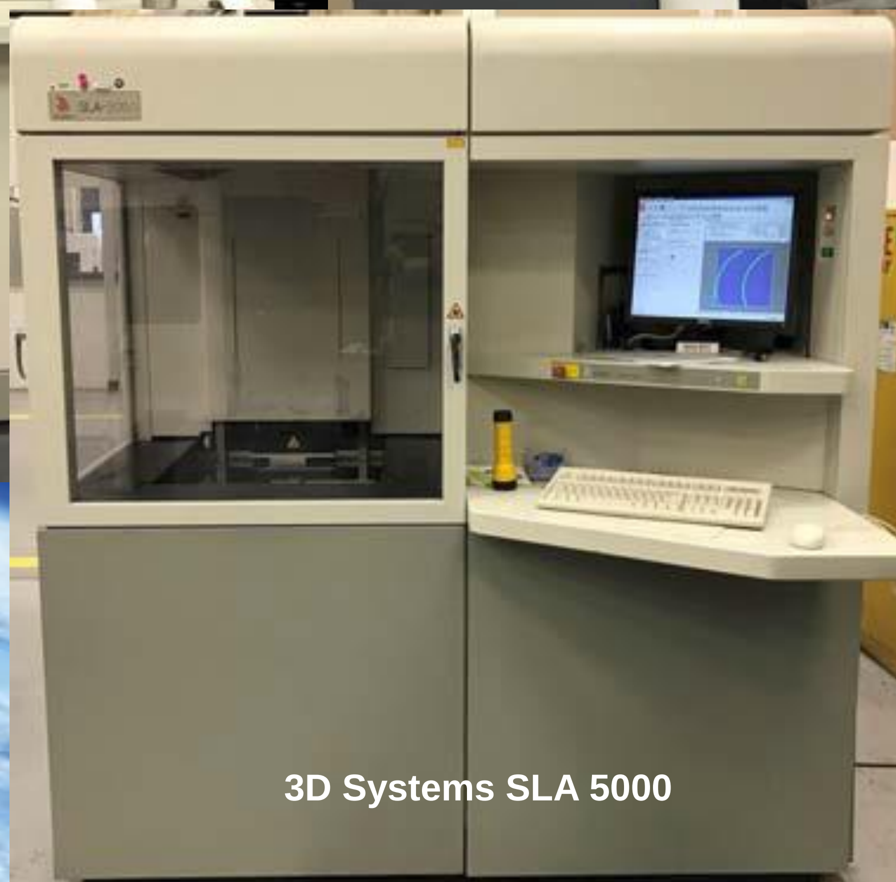
- Implementation of AM components for next generation of rocket engines
- Characterization of applicable alloys in AM
- Rationales for flight certification for NASA and our vendors
- Risk reduction and data share in pursue of smart vendor base
- Development of new alloys for AM processes (i.e. copper)
- Next generation AM technologies (Additive/Subtractive System)

Embedded Video

MSFC AM Machines: Polymer

3D Systems Viper

Stratasys Fortus 900mc

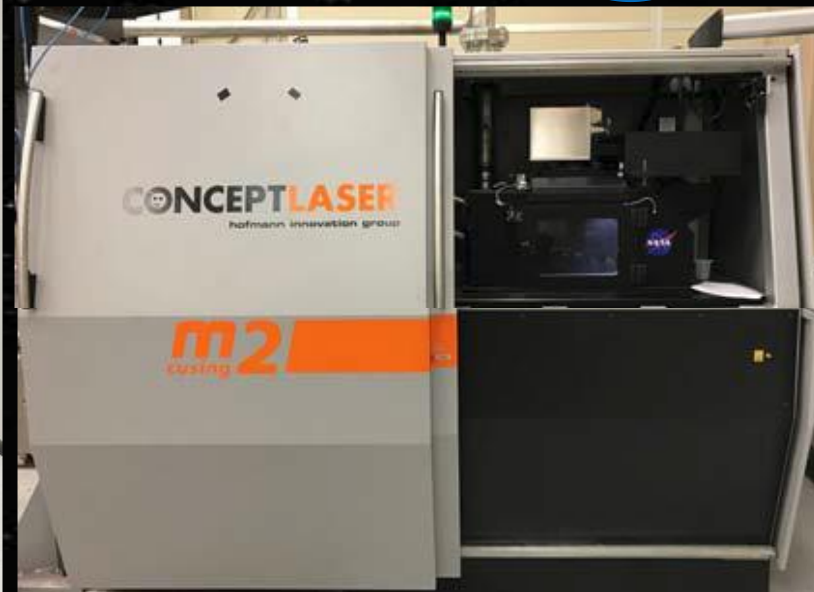


3D Systems SLA 5000

Video

MSFC AM Machines: Metals

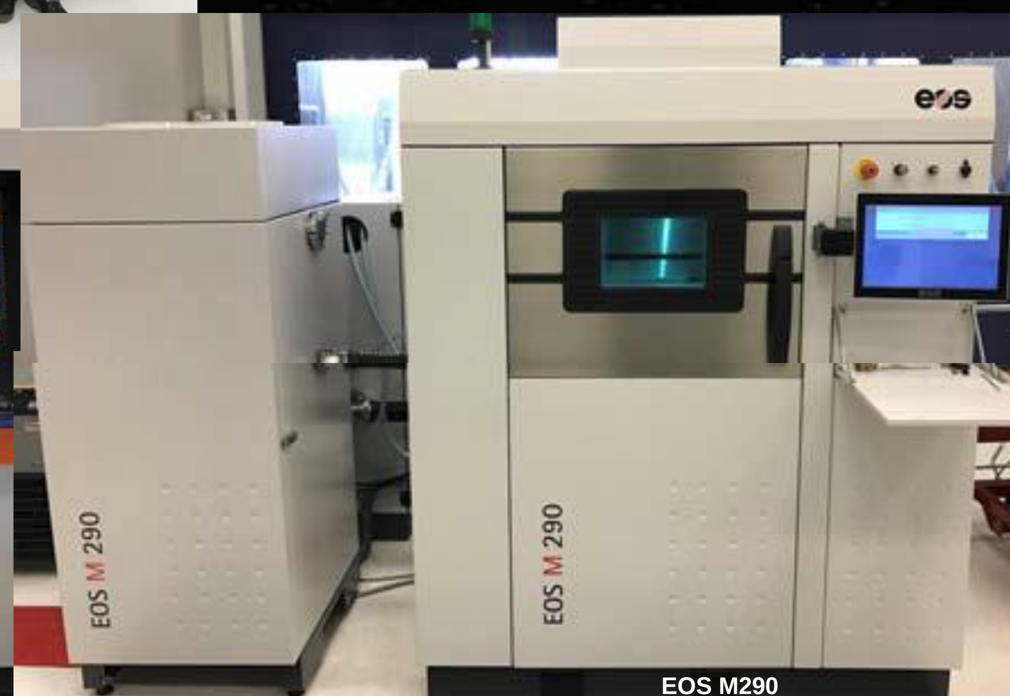
Concept Laser X-Line 1000R



Concept Laser M2

ARCAM S400

Concept Laser M1



EOS M290

Significant Effort in AM Characterization

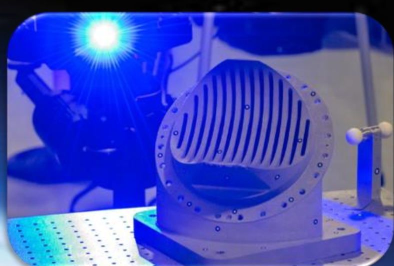
Performance

Powder

MAPTIS

Characterization

Process Parameters

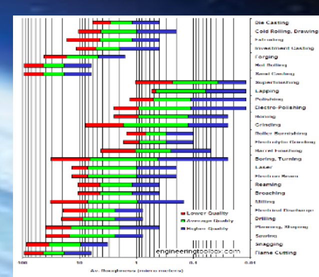


Dimensional & NDE Inspections

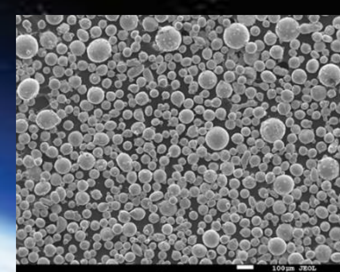
Digital Thread

Heat Treatment

Test & Properties



Surface Finish



Microstructure

What is MSFC's Role in AM ?

- Risk Reduction & Technology Transfer
- Vendor Development & Smart Buyer
- Certification Rationale & Guidance
- Anomaly Resolution

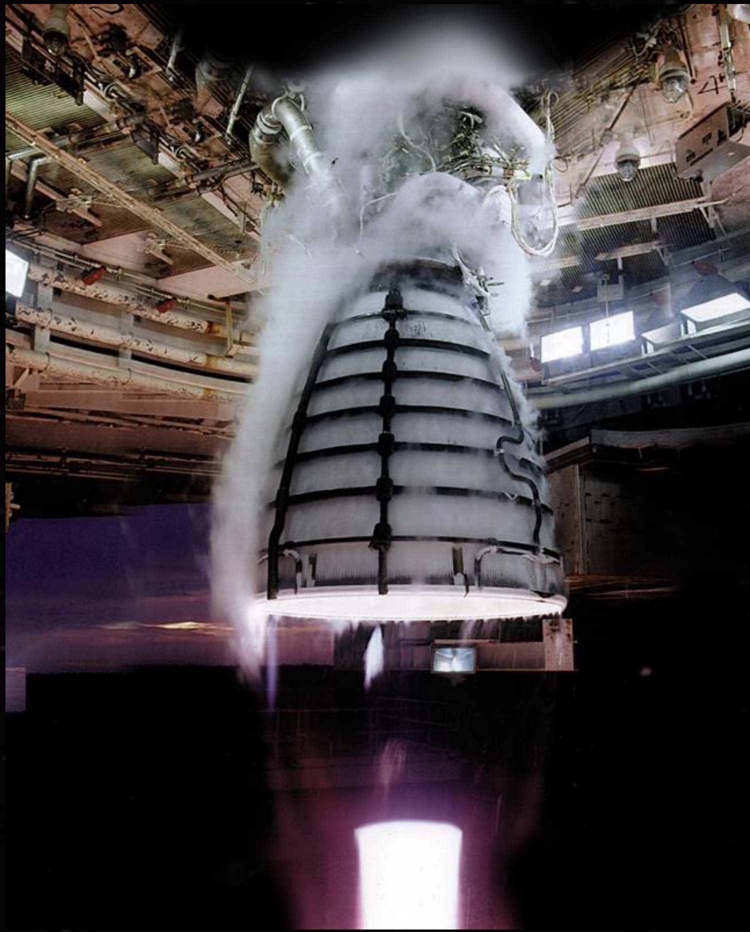
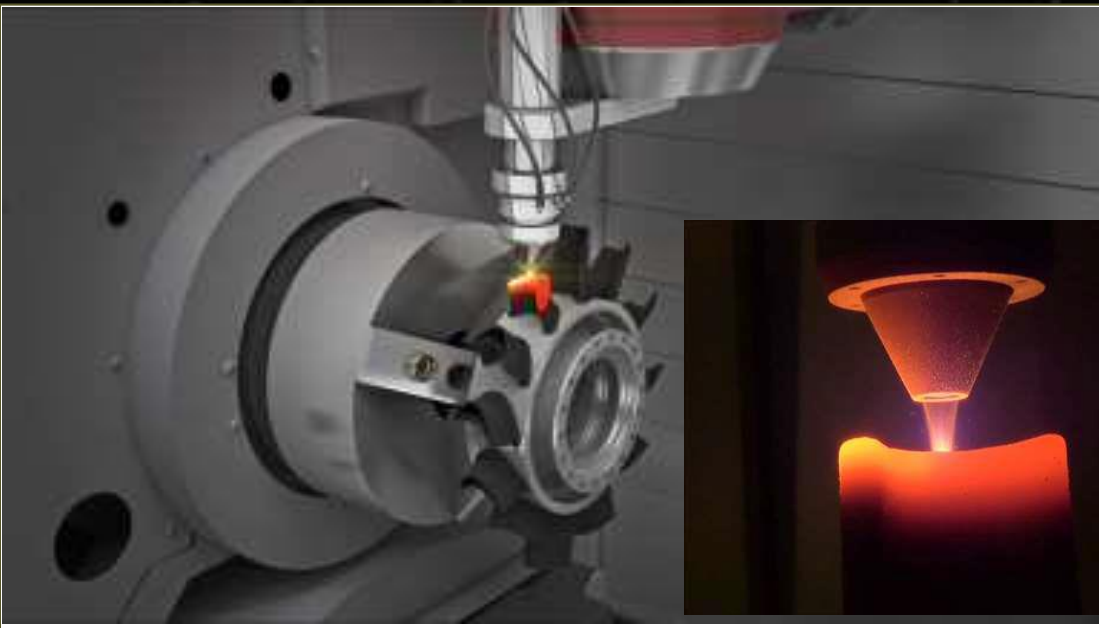


Image Credit: Aerojet Rocketdyne

Bi-metallic AM Development

- Although SLM/Powder Bed Fusion satisfies a lot of AM manufacturing needs, it has limitations.
- Some limitations are; build envelope size, surface finish requirements, speed, component design or multi-material nature of application.
- Some of these issues have been solved and demonstrated by the following collaboration between NASA and DMG MORI Utilizing DMG MORI LT4300 system

DMG MORI Hybrid System (LT4300)

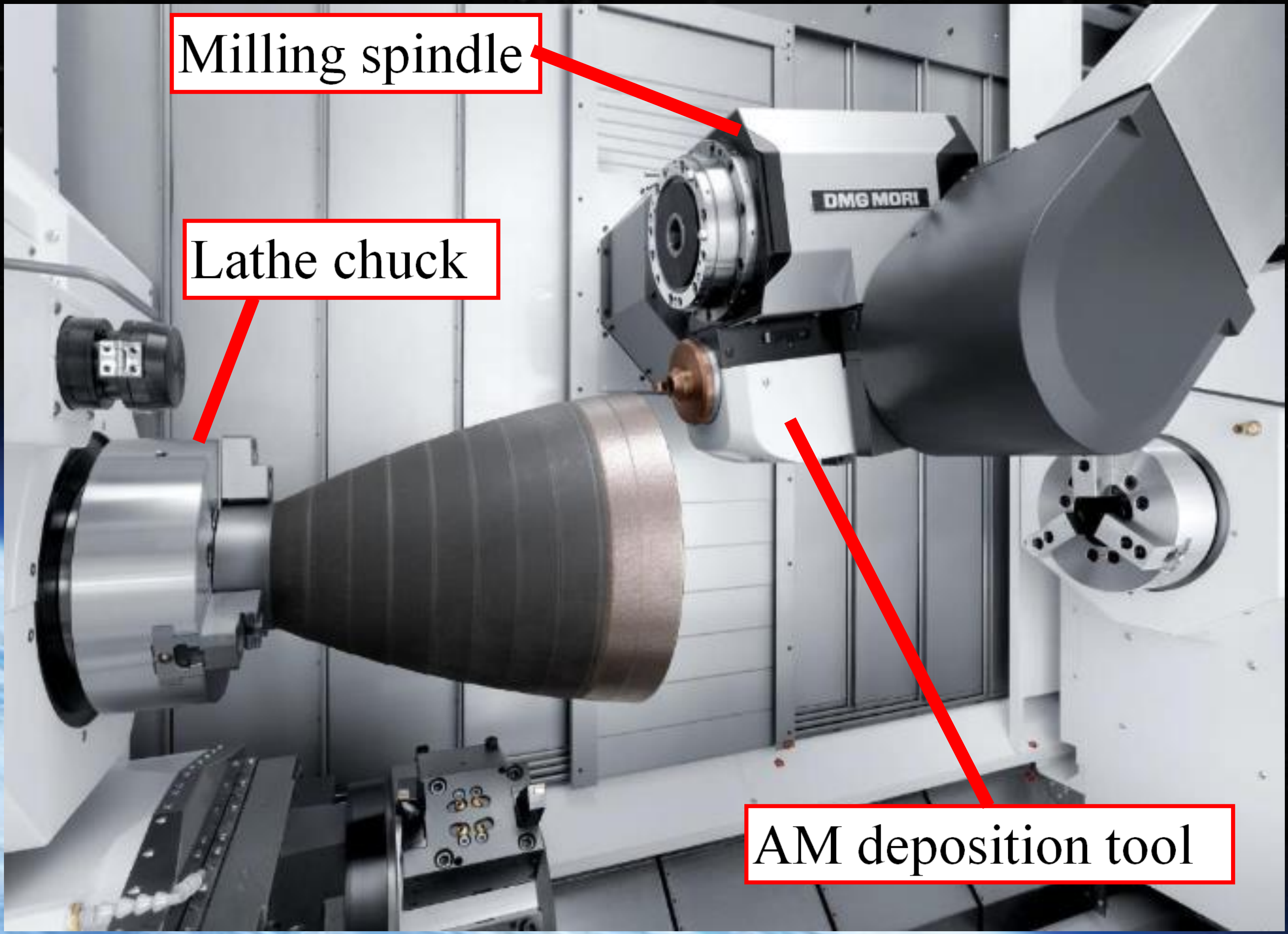


Embedded Video

- Integrated machining/grinding during build
- Single build from multiple alloys
- Graded alloys
- Build on existing substrates/repair
- High deposition rates
- Lower cost metal powder
- Large build volume and scalability

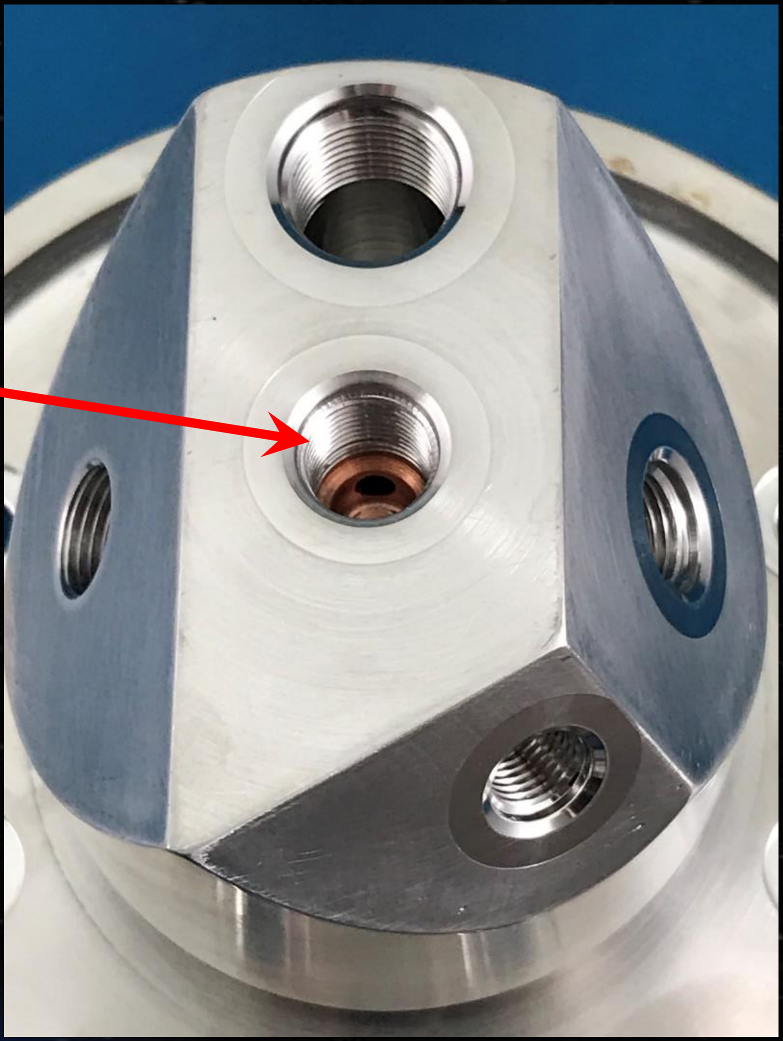
Bi-metallic AM Development

DMG MORI LT4300

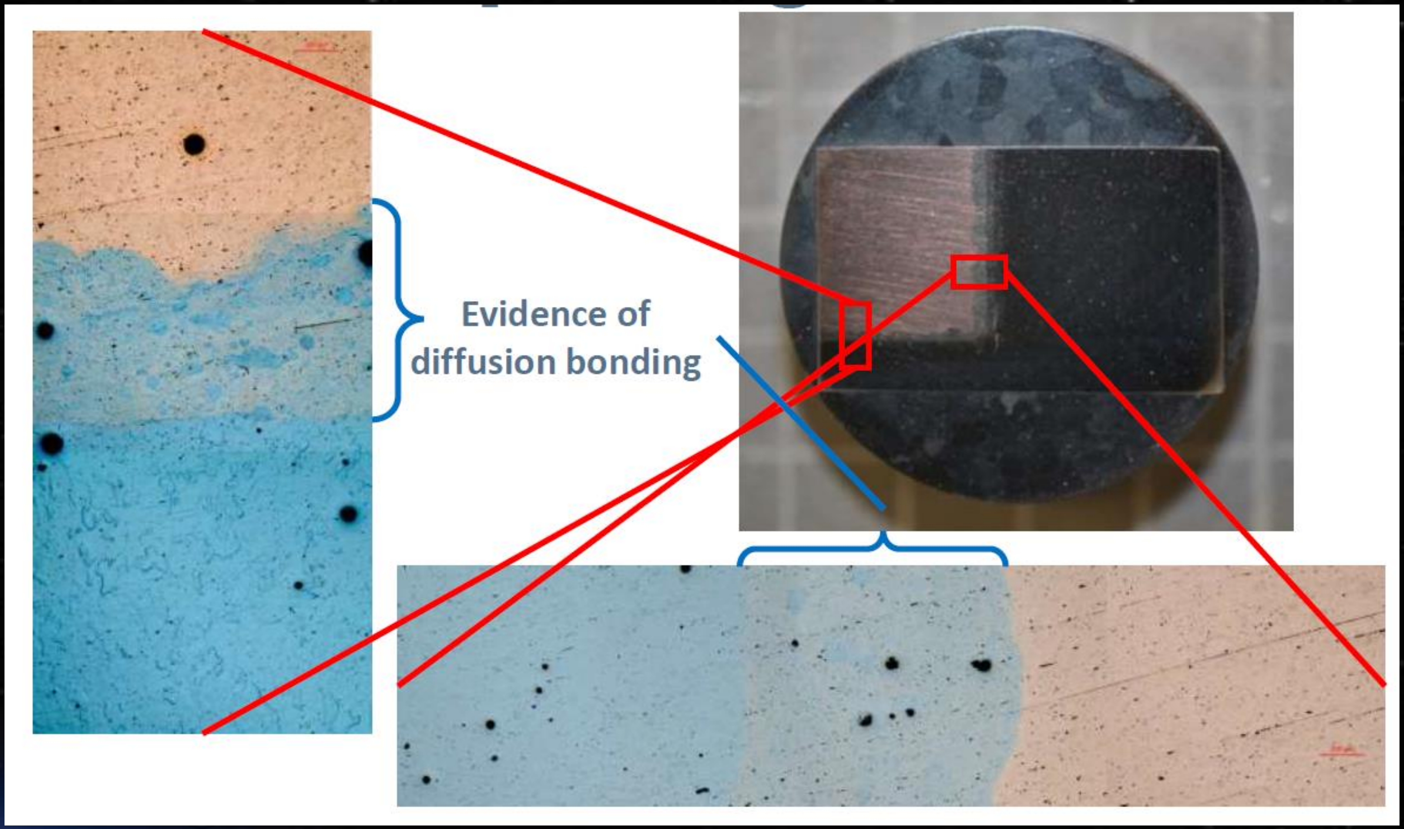


Bi-metallic AM Development

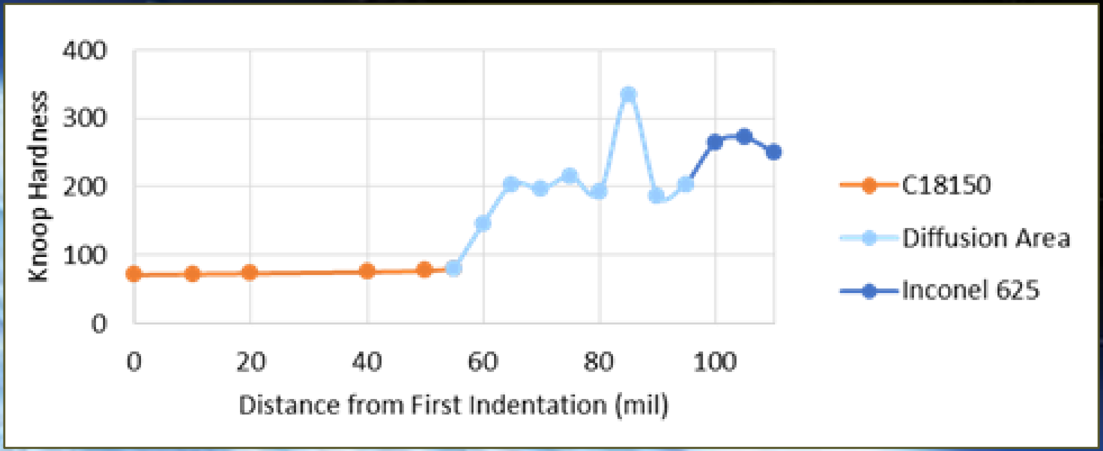
Fabricated Two ASI



Bi-metallic AM Development



Optical microscopy images of bond area



Bi-metallic AM Development

Igniter test fixture for hot fire testing

Bi-metallic AM Development

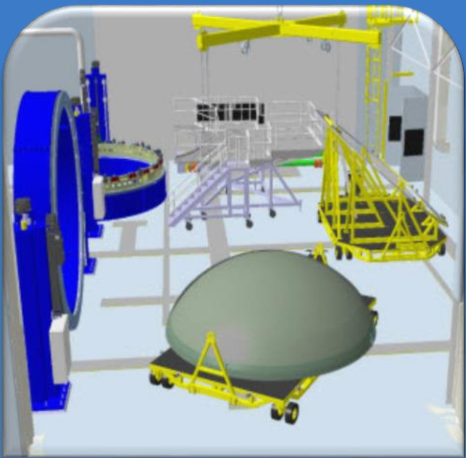
33 Hot-fire Test (July12, 2017)
Infrared image of igniter exhaust flame

Videos

Large Scale Composites Mfg.

Large Scale Composites Mfg.

Digital Engineering Suite



Manufacturing Simulations

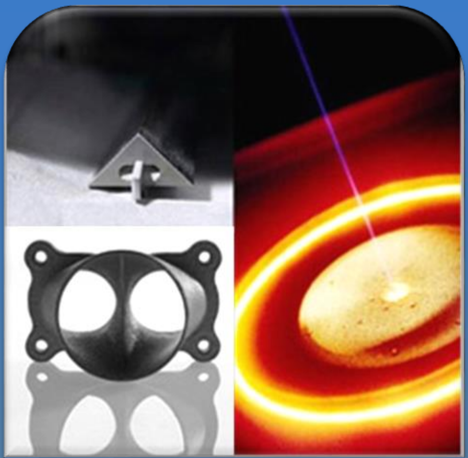
- Facility Verification
- Kinematic Analysis
- Interference Analysis
- Off-line Programming
- Assembly/Disassembly Verification
- Model-based Instructions

Mfg Planning and Execution

- Paperless delivery of work instructions
- Controls Build of Engineering Released Data
- Process Planning, Execution, and Quality
- As-Built BOM and Data Package

Structured Light Scanning

- Drive Mfg Processes
- As-Built CAD Parts
- As-Built CAD Assemblies
- Virtual Fit Checks
- Mfg Tooling Setup/Verification
- Reverse Engineering
- Quality Inspection and Acceptance
- Facility/Equip Modeling (MAF)



Additive Manufacturing

- Technologies
  - SLM
  - EBM
  - FDM
- Materials
  - Titanium
  - Aluminum
  - Inconel
  - Plastic
- Uses
  - Rapid Prototypes
  - Complex Part Mfg
  - In-space Manufacturing

Four Technology Areas – One Solution

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Bi-metallic AM Development

Successful Test Results

The second additively built bi-metallic igniter, first of its kind was installed and test fired successfully 33 times at NASA MSFC propulsion test facility in July 2017. These were low-pressure, hot-fire component testing to simulate the cryogenic tank-head operation of the igniter during engine start-up.

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