Additive Manufacturing at NASA/MSFC – Steven Burlingame

Hybrid Manufacturing of Bi-Metallic Liquid Rocket Engine Igniter – Greg Hyatt, Ph.D.

ADDITIVE MANUFACTURING USERS GROUP

2018 AMUG 30th Annual Education and Training Conference

St. Louis Union Station
St. Louis, Missouri
April 8 – 12, 2018

National Aeronautics and Space Administration
Marshall Space Flight Center

Additive Manufacturing at NASA/MSFC

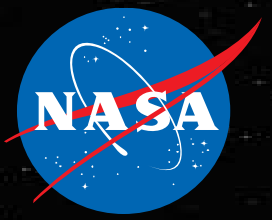
Transforming Design & Manufacturing

Steve Burlingame

Advanced Manufacturing Assistant Chief

NASA / MSFC

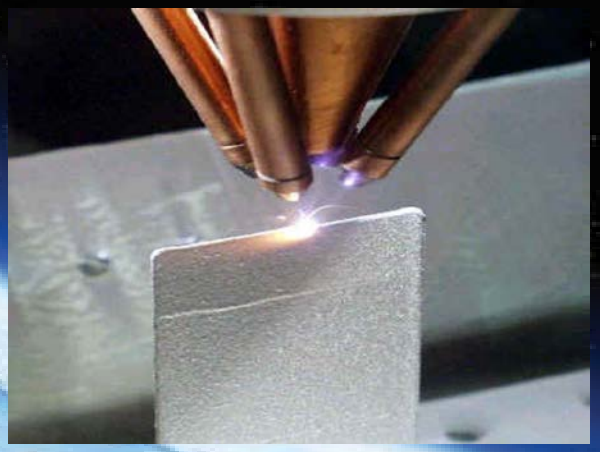
Agenda

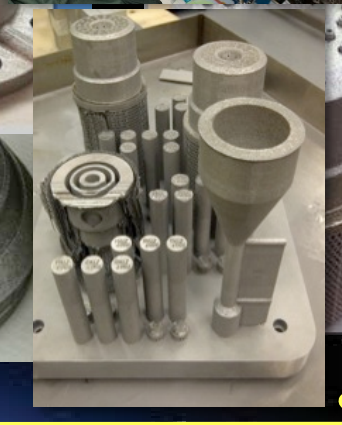


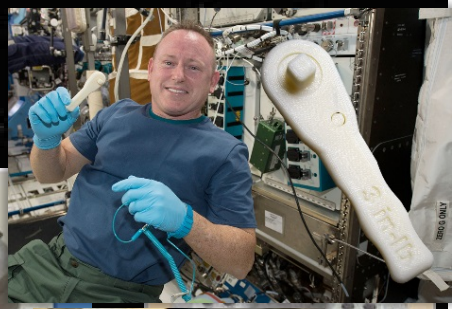
- Our History in AM
- Our AM Efforts
  - Manufacturing “In Space”
  - Manufacturing “For Space”
- AM Developments and Goals
- Hybrid AM Developmental Efforts
  (Collaboration with DMG MORI – Dr. Greg Hyatt)

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







1991

2000

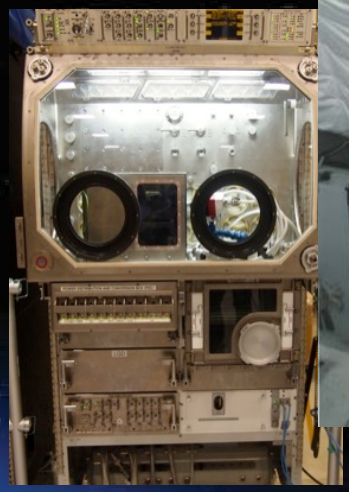
2010

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

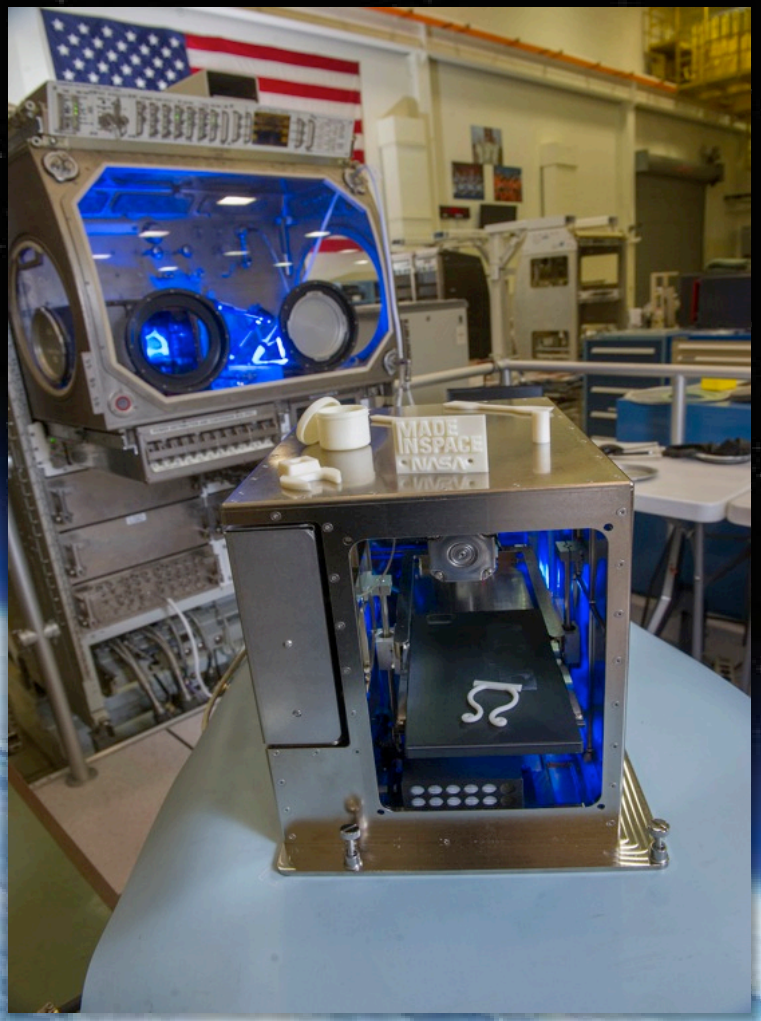
In-Space



AM Manufacturing “IN-Space”

Why is it important?

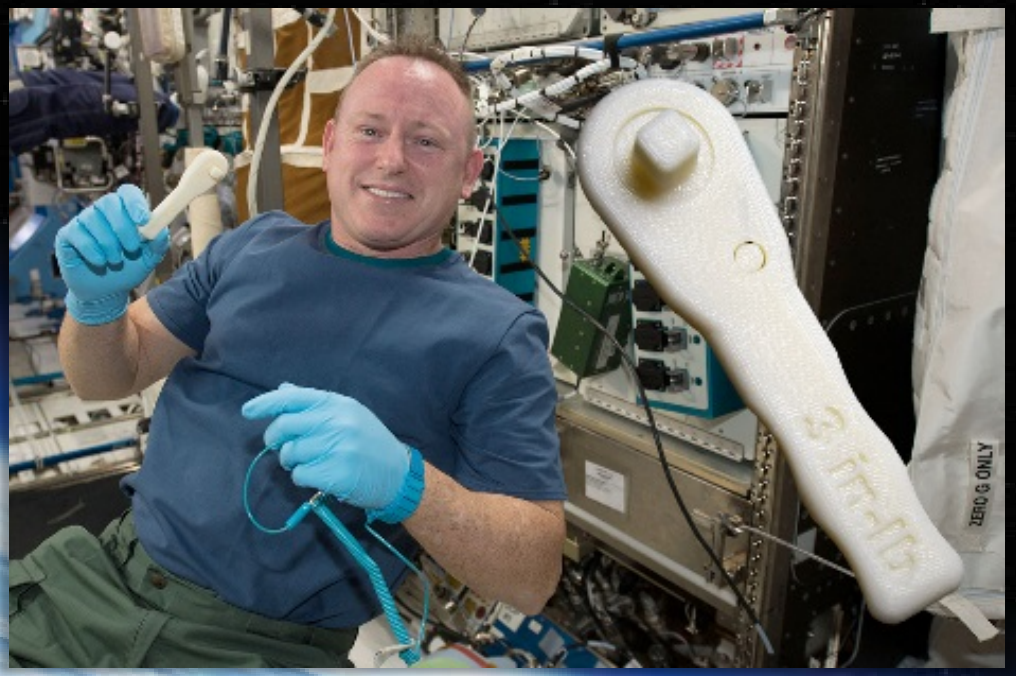
AM is a critical technology for deep space explorations, part replacements, tools and habitats.



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

3D Print Technology Demonstration

- 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”

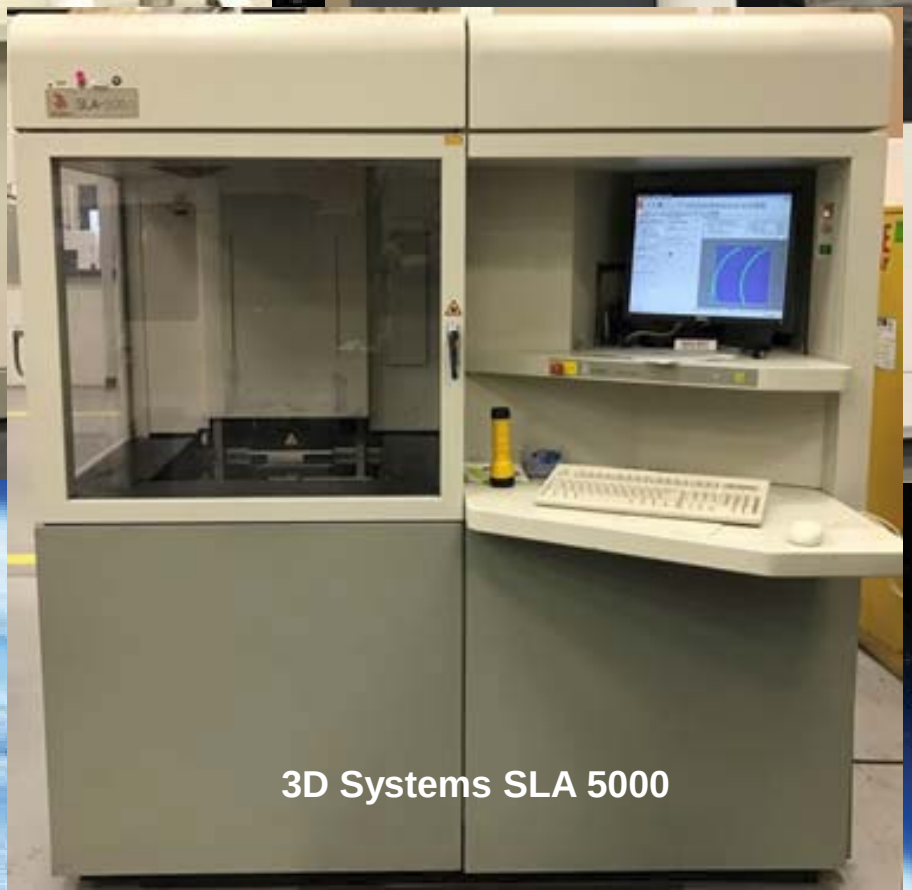
NASA MSFC is looking to Additive Mfg. and innovative designs to reduce manufacturing cost and schedule and help affordability of access to Space.

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)

MSFC AM Machines: Polymers

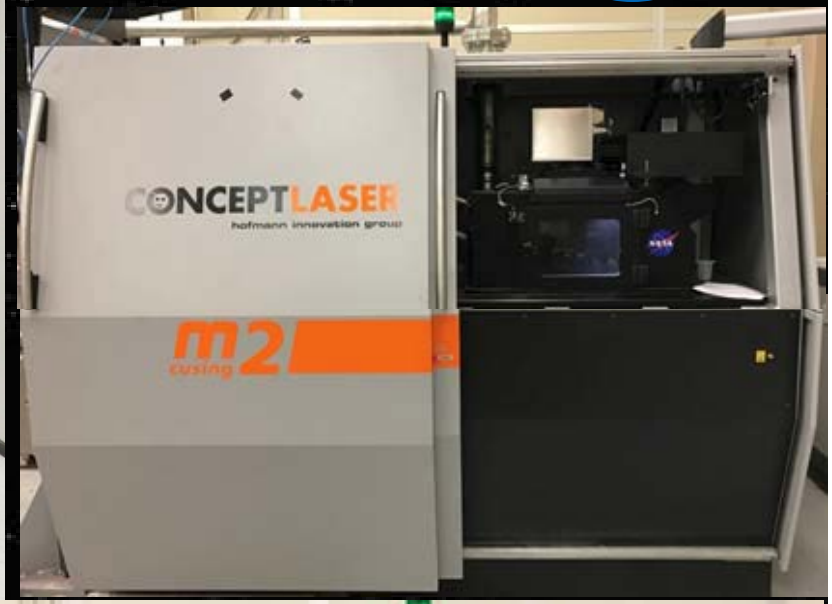
3D Systems Viper



3D Systems SLA 5000

Stratasys Fortus 900mc

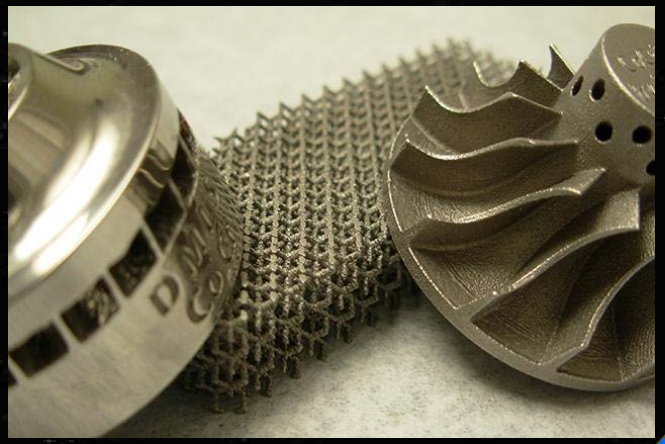
MSFC AM Machines: Metals



Significant Effort in AM Characterization

Performance

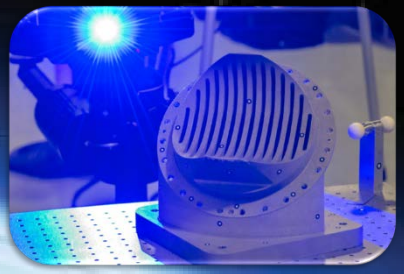
MAPTIS



Characterization

Powder

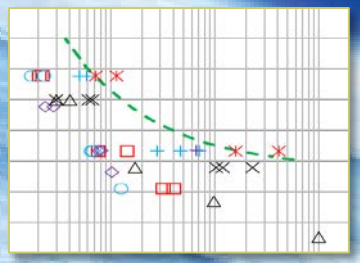
Process Parameters



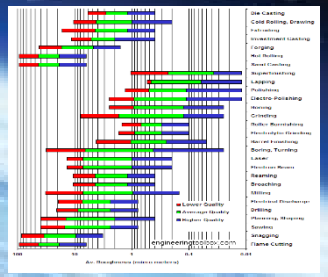
Dimensional &
NDE Inspections

Digital Thread

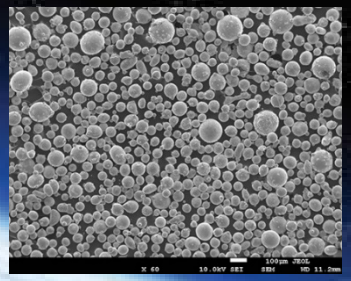
Heat Treatment



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

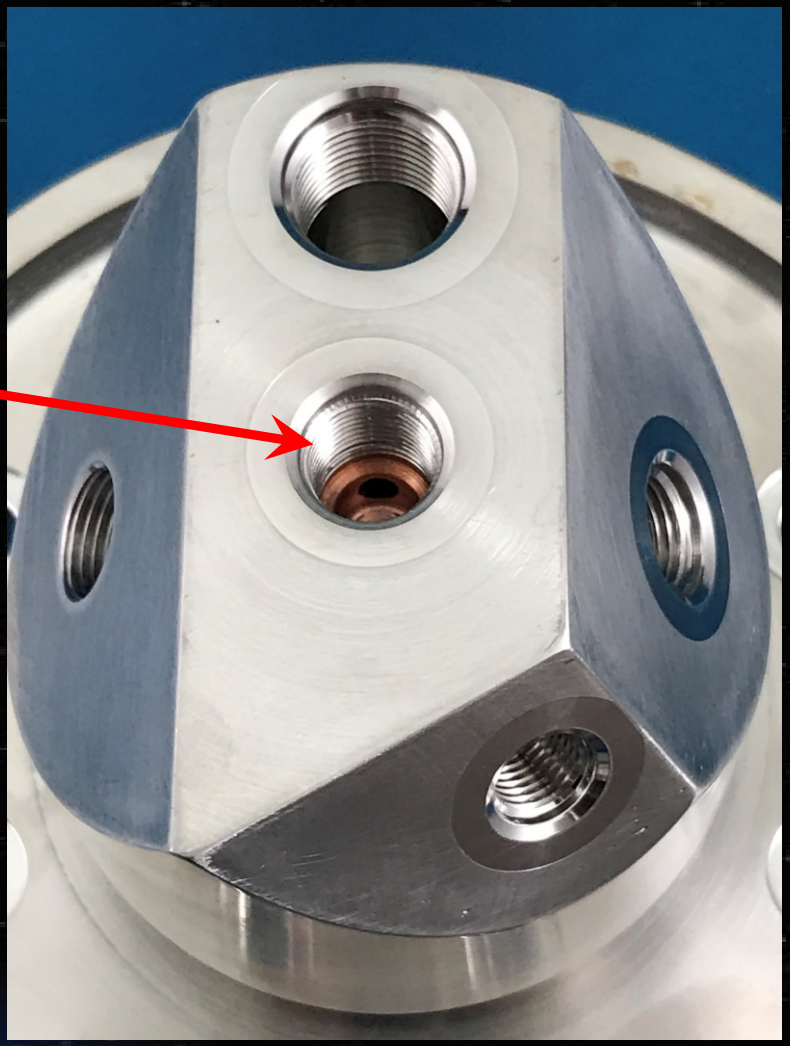
Image Credit: Aerojet Rocketdyne

Bi-metallic AM Development

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

Bi-metallic AM Development

Fabricated Two Liquid Rocket Engine Igniters



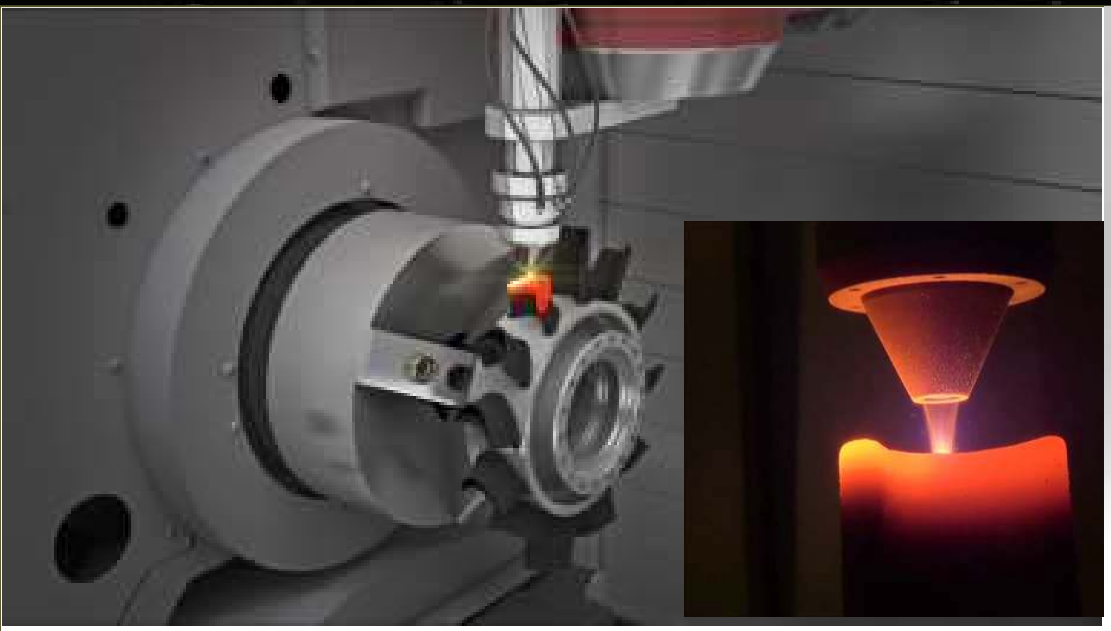
Bi-metallic AM Development

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.

Backup Charts

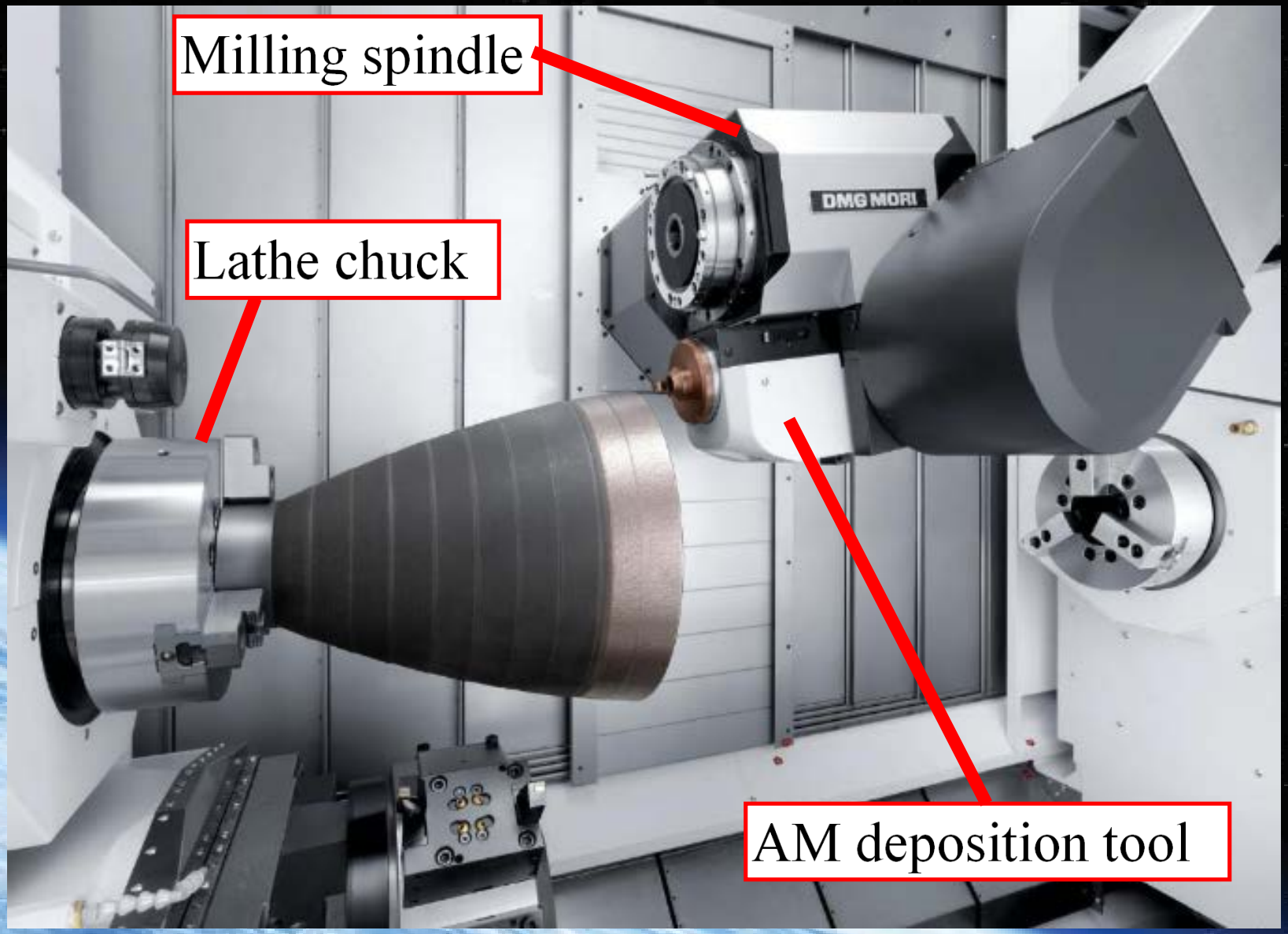
DMG MORI Hybrid System (LT4300)



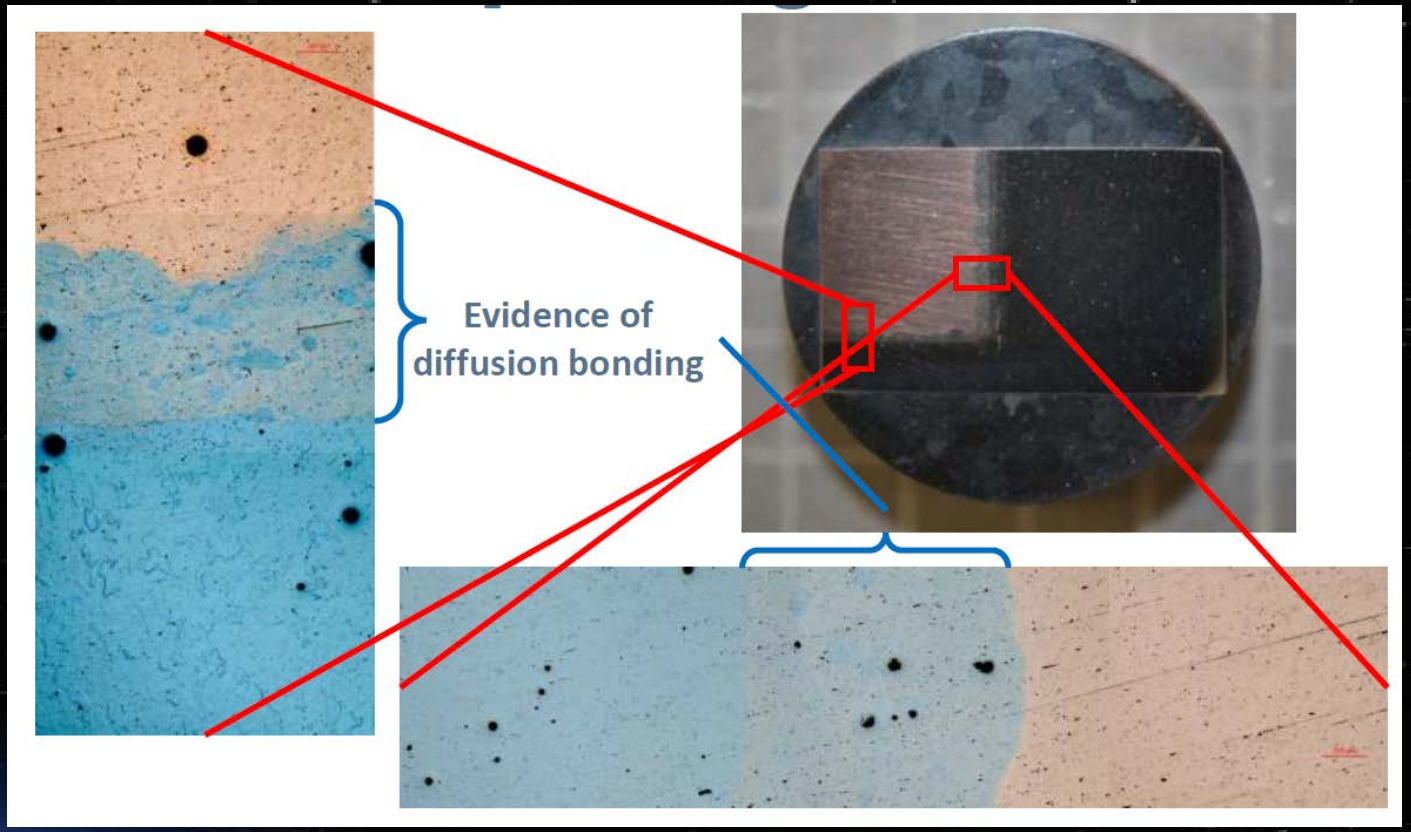
- Integrated machining/grinding during build
- Single build from multiple alloys
- Graded alloys
- Build on existing substrates/repair
- High deposition rates
- Lower cost metal powder
- Large build volume and scalability

Bi-metallic AM Development

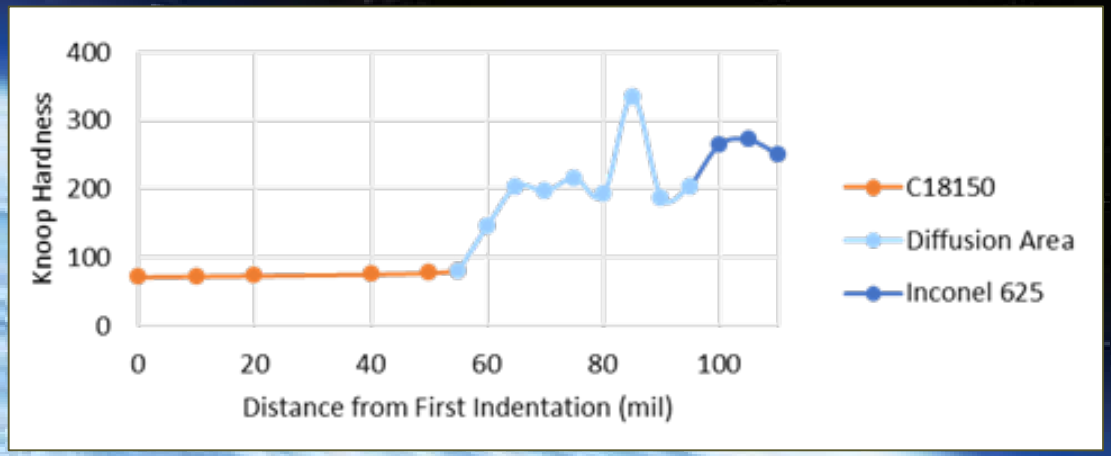
DMG MORI LT4300



Bi-metallic AM Development



Optical microscopy images of bond area



Bi-metallic AM Development

Igniter test fixture for hot fire testing

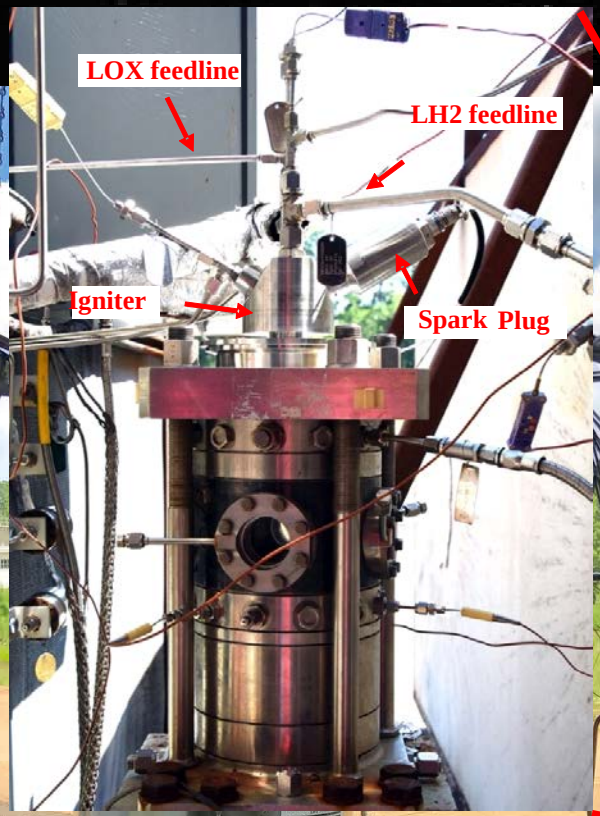


Figure 1. -fire testing.

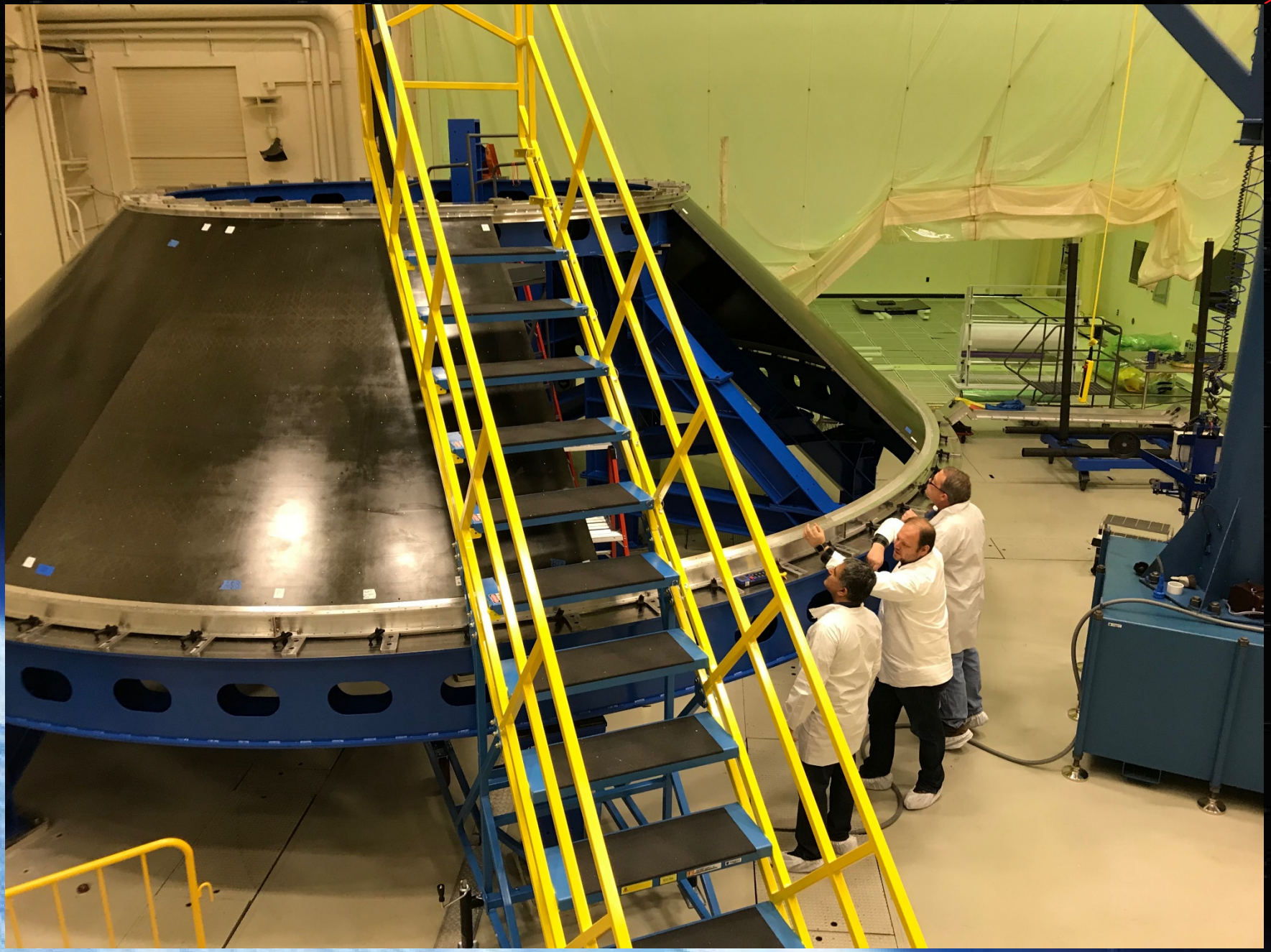
Bi-metallic AM Development

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

Videos

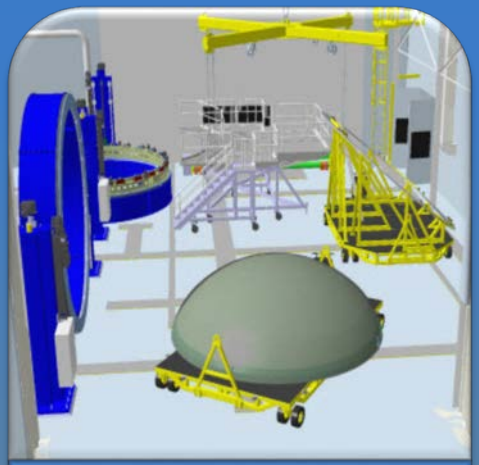
Large Scale Composites Mfg.

Large Scale Composites Mfg.



Payload Adapter for Space Launch System

Digital Engineering Suite



Manufacturing Simulations

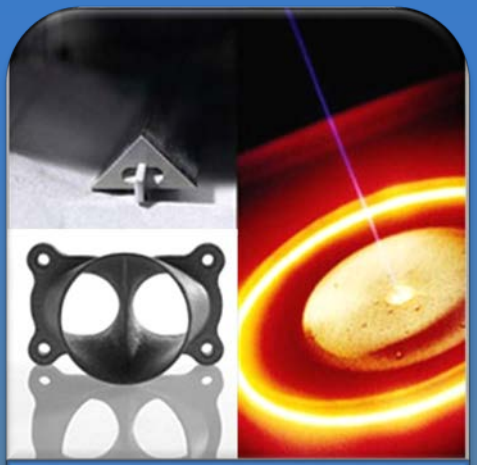
- Facility Verification
- Kinematic Analysis
- Interference Analysis
- Off-line Programming
- Assembly/Disassembly Verification
- Model-based Instructions

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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