NSRP JOINT PANEL MEETING
Buffalo, NY
October 16th – 17th

Additive Manufacturing at EWI

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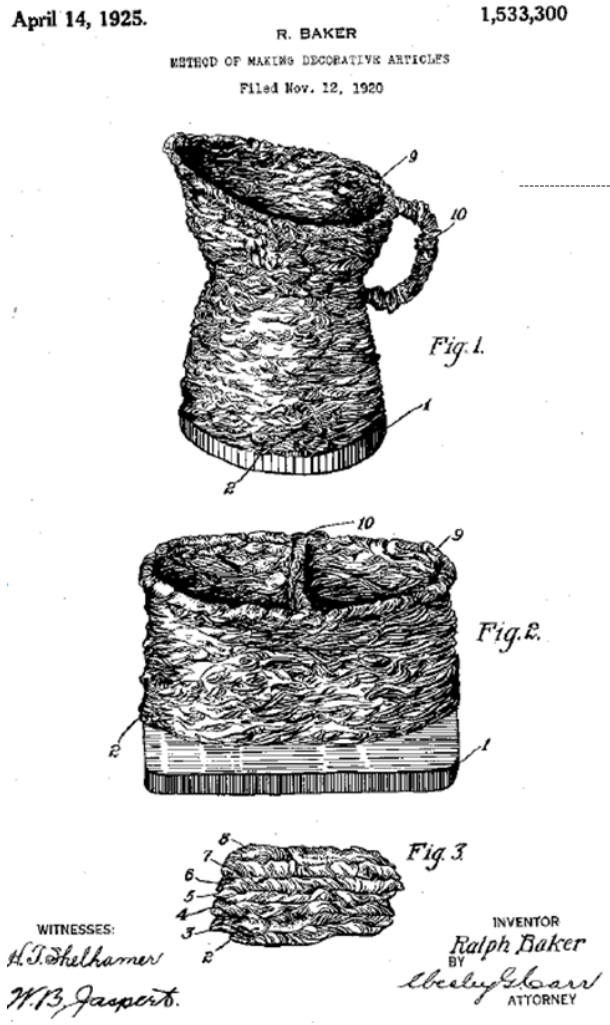
EWI
We Manufacture Innovation

Outline

- About EWI
- Machine Capabilities
- Technical Capabilities
- Case Studies
- Centers and Consortia


April 14, 1925. 1,533,300

R. BAKER

METHOD OF MAKING DECORATIVE ARTICLES

Filed Nov. 12, 1920

Fig. 1.

Fig. 2.

Fig. 3

WITNESSES:
H. T. Shelhamer
W. B. Jaspert.

INVENTOR
Ralph Baker
BY
Cheesley Gleason
ATTORNEY

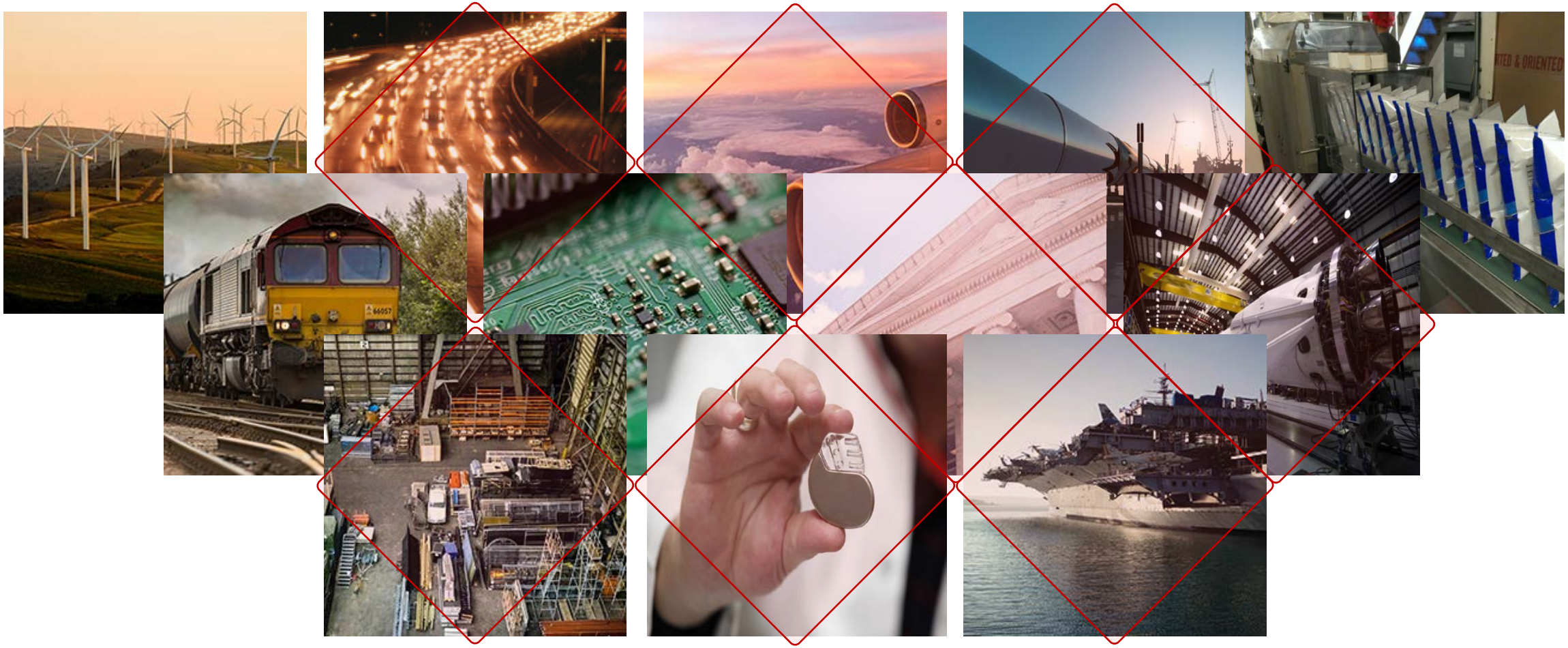
This invention relates to **utilizing an electric arc** such as is ordinarily employed for electric welding, **for the formation of** deposits to produce receptacles or containers of ornamental and **useful shape**

EWI: Overview

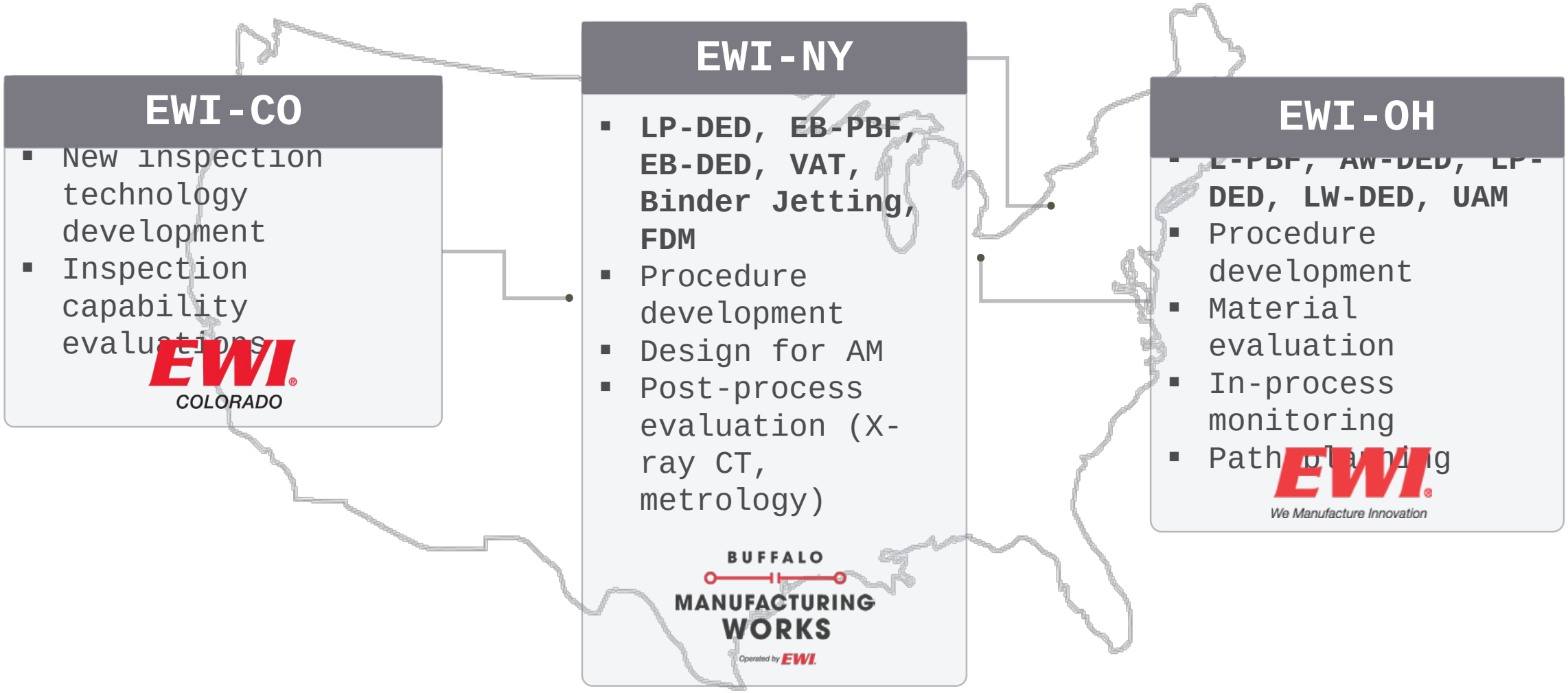
EWI is an advanced engineering services institute that **develops** and **implements** manufacturing solutions around materials joining

- **Non-profit applied manufacturing R&D institute**
  - 160,000+ ft^2 of full-scale labs spread across 3 facilities
  - $40M+ in state-of-the-art capital equipment
  - 160+ engineers, technicians, industry experts and member advocates
- **Membership-based organization**
  - 200+ active members
  - Inquiry, design review, library services
- **Centers & Consortia**
  - Additive Manufacturing Consortium, ASTM AM CoE, Forming Center, Aerospace Forming Consortium

EWI: Industries



Additive Manufacturing: Locations



EWI-CO

- New inspection technology development
- Inspection capability evaluations

EWI COLORADO

EWI-NY

- **LP-DED, EB-PBF, EB-DED, VAT, Binder Jetting, FDM**
- Procedure development
- Design for AM
- Post-process evaluation (X-ray CT, metrology)

BUFFALO MANUFACTURING WORKS
Operated by EWI

EWI-OH

- **L-PBF, AW-DED, LP-DED, LW-DED, UAM**
- Procedure development
- Material evaluation
- In-process monitoring
- Path planning

EWI We Manufacture Innovation

Additive Manufacturing: Printing Equipment

- **Build Envelope:**
  - 250×250×325 mm
- **Materials:**
  - Alloy steels (4140)
  - Ni alloys (Haynes 282, Inco 625, Inco 718)
  - Stainless steels (316, 420, 2205)
  - Refractory metals (Zr, W, Mo)

Laser powder bed fusion

- **Build Envelope:**
  - 125×125×50 mm
- **Materials:**
  - All metal powder
- **Capabilities:**
  - Open access to path planning, viewing ports, motor I/O, laser delivery

Laser powder bed fusion

- **Build Envelope:**
  - 250×250×380 mm
- **Materials:**
  - Stainless steel (316L)
  - Ni alloys (Inco 718)
  - Ti64, TiAl
  - Magnesium
  - CoCrMo

EB powder bed fusion

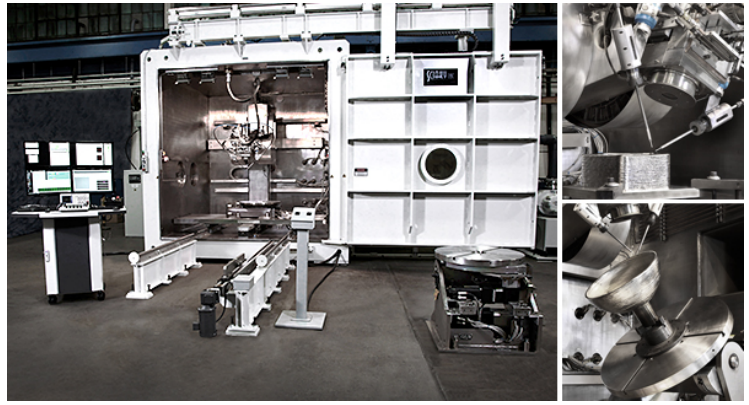
Additive Manufacturing: Printing Equipment

- **Build Envelope:**
  - 160×65×65 mm
- **Materials:**
  - Metals
  - Ceramics
  - Glass
  - Sand castings

Binder jetting

- **Build Envelope:**
  - 1.5×1.5×2.1 m
- **Materials:**
  - Metals
- **Capabilities:**
  - 5-axis capabilities

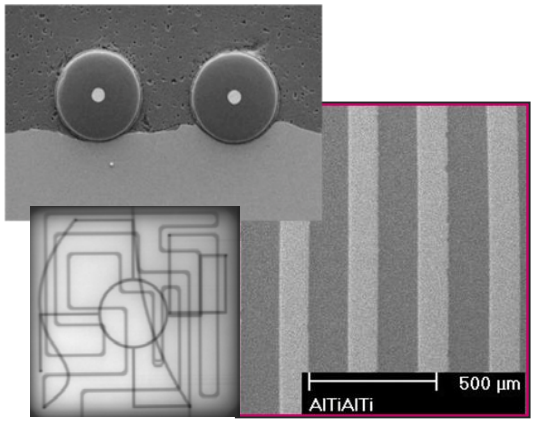
Laser directed energy deposition



- **Build Envelope:**
  - 1.8×1.2×1.6 m
- **Materials:**
  - Metals
- **Capabilities:**
  - Multi-axis capabilities
  - Closed loop control

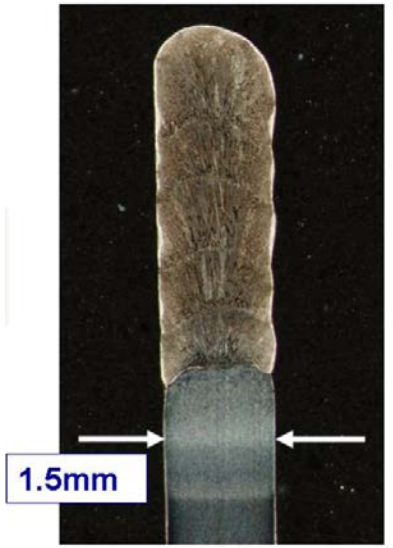
EB directed energy deposition

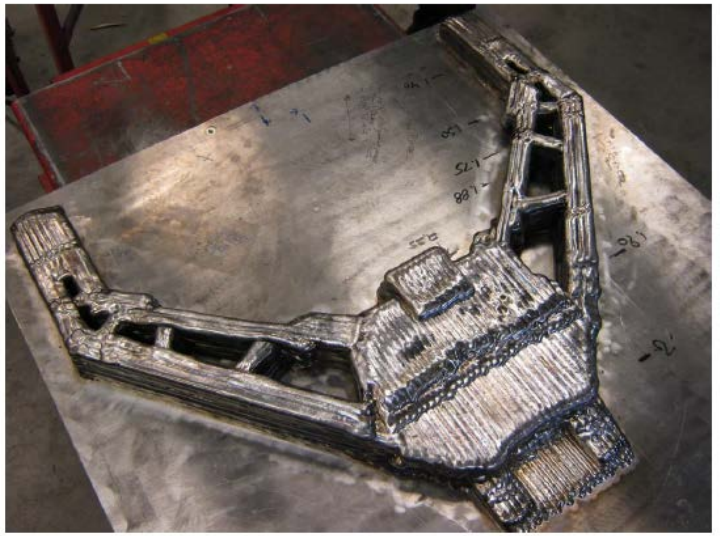
Additive Manufacturing: Printing Equipment



- **Build Envelope:**
  - 1.8x1.8x0.9 m, 3-axis CNC
- **Materials:**
  - Copper and aluminum
- **Capabilities**
  - Solid state, full metallurgical bond
  - Enables multi-material system

Sheet lamination

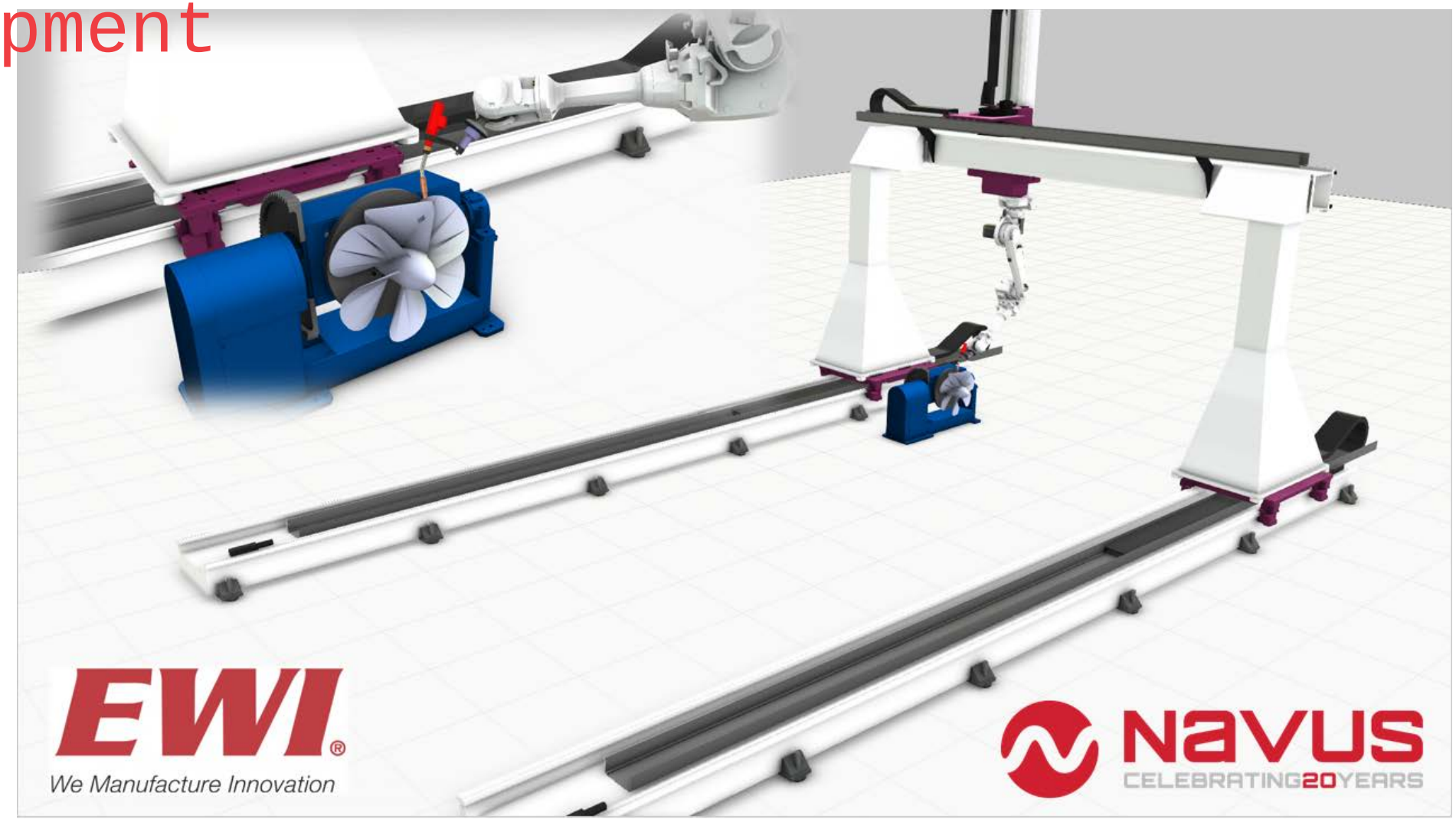




- **Capabilities**
  - Energy source equipment readily available
  - Core process is well understood
  - Feedstock Availability
  - Deposition speeds

Robotic laser and arc-based AM

Additive Manufacturing: Printing Equipment



COMING SPRING 2020

Additive Manufacturing: Characterization Equipment

POWDER	NDE	METROLOGY	MECHANICAL	METALLOGRAPHY
Particle Size Dist.	Ultrasonic	Structured Light	Tensile	Digital Photography
Hall Flow	Phased Array	Surface Char.	Bend	Linear Image Analysis
Apparent Density	Eddy Current		Impact	Chemical Analysis
Tap Density	Radiography		Fatigue	O2/N2 Analysis
ONH Content	CT		Crack Growth	SEM/EDS/EBSD
Powder Porosity	Mag. Particle		CTOD	TGA
Powder Morphology	Liquid Penetrant		KIC	DSC
			R-Curve	Hardness Mapping
			Residual Stress	Grain Size
			Resonant Fatigue	Percent Ferrite
				Porosity/Inclusion
				Morphology Char.

Additive Manufacturing: Technical Capabilities

	MATERIALS	PROCESSING	DESIGN	QUALITY CNTL.
ESTABLISHED	Material characterization Weldability Heat treatment Powder characterization Powder recycling	Multi-process Process selection Parameter development Post-processing	Build layout Part orientation Support strategy AM part identification Design for additive	In-process monitoring Surface metrology Non-destructive eval. Lab safety
DEVELOPMENT	Microstructure control Gradient components AM-to-cast welding AM-to-wrought welding Feedstock composition	Large scale deposition Hybrid processing Gas optimization Skin optimization Dynamic beam profiles Novel scan strategies	Dynamic path planning Feature-specific planning AM process modeling	Next gen. monitoring Feed-forward control Feed-back control Machine certification Machine learning Process qualification

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AM Case Studies

Additive Manufacturing: Projects Types

1. **Commercial Projects:**
   - EWI confidentially solves individual companies metal AM challenges
2. **Government Projects:**
   - EWI performs research and development projects on metal AM topics to drive AM technology forward
3. **Centers & Consortia:**
   - Additive Manufacturing Consortium (AMC)
   - ASTM AM Center of Excellence
   - America Makes
4. **Internally Funded Research and Development:**
   - EWI invests in technology development through IRD projects to support its membership

Parameter and Build Strategy Development

Objectives:

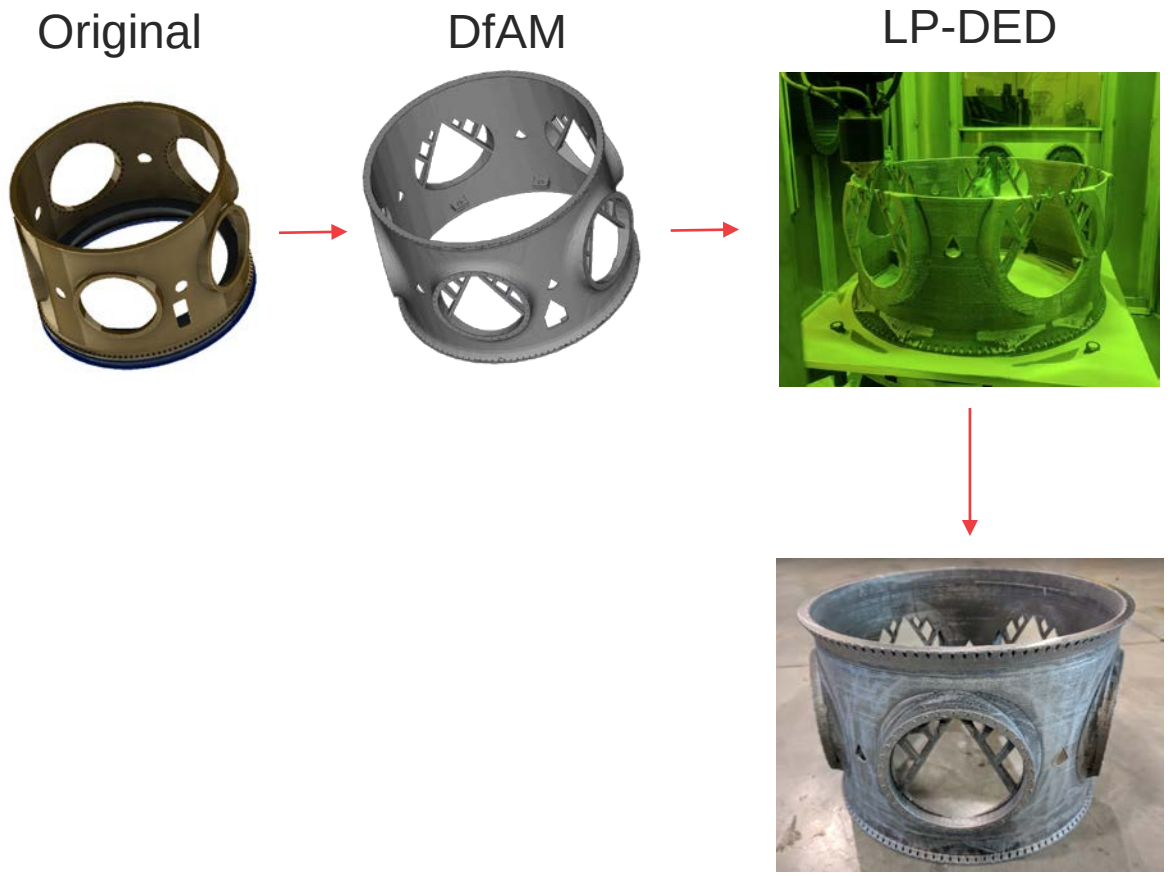
- Develop material parameters sets for PBF and DED
- Develop build strategies for part prototypes

Solution:

- Leverage our legacy expertise in weldability and parameter development
- Apply years additive process experience

Outcome:

- Developed parameters for 40+ metal alloy systems for L-PBF
- Developed numerous build strategies across multiple metal



Ti64 demo build of a secondary payload adapter

Application of robotic arc-based DED

Objective:

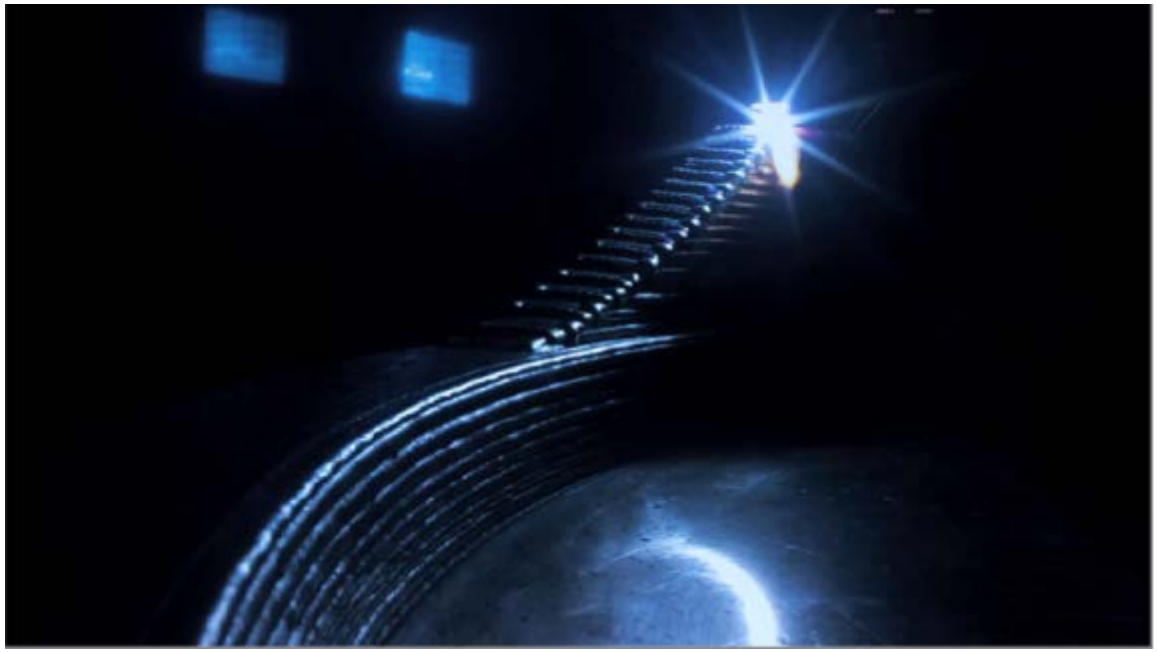
- Evaluate the feasibility AW-DED to build 308 stainless components

Solution:

- Part built with 3/8” extra width on each side to allow for edge variation
- 0.5” added to ends

Outcome:

- Billet/casting required to machine ≥ 8” x 8” x 42”
- Process results in an 85% reduction in material required
- 15 hours of arc-on time, 2 hours of interlayer cleaning



Faster CT

Objective:

- Decrease the acquisition and reconstruction time

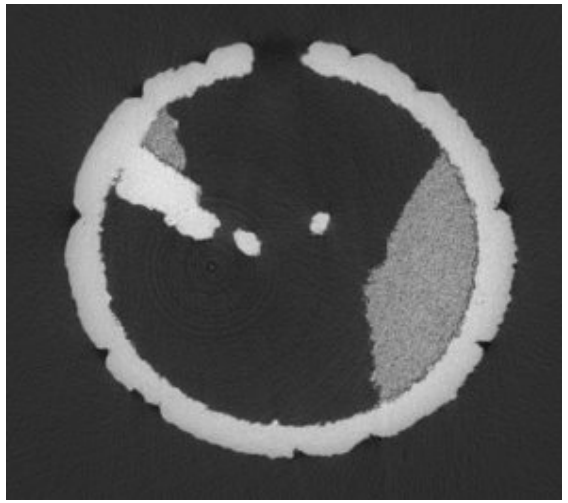
Solution:

- Take advantage of the static nature of manufacturing XCT applications (i.e. no movement)

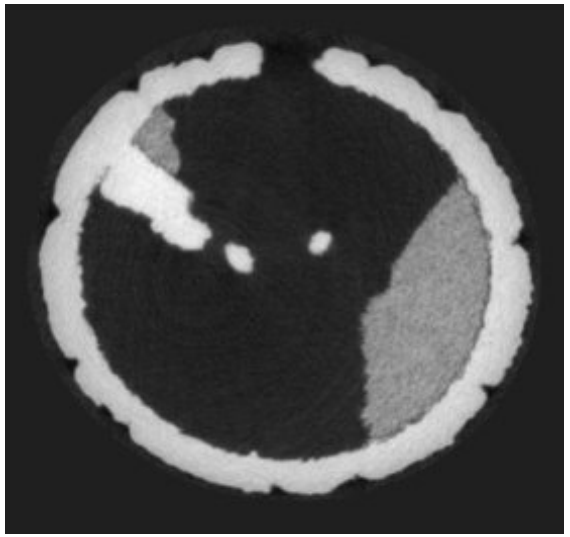
Outcome:

- 3X to 10X speed improvements for complex shapes including multi-material assembles

Traditional



Faster CT



Surface Topography for L-PBF Quality Monitoring

Objectives:

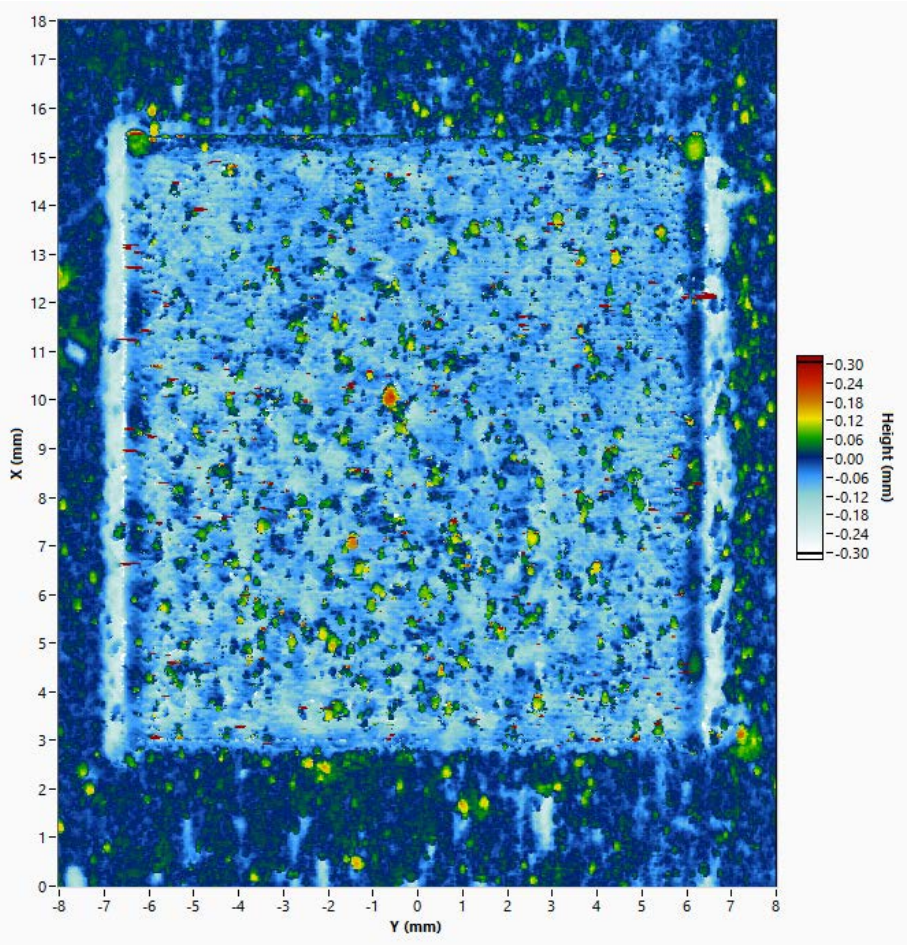
- Demonstrate the capability detect volumetric flaw generation based on surface topography metrics
- Develop and evaluate in-line repair processes
- Demonstrate closed-loop repair performance

Solution:

- Provide the capability to measure topography layer-by-layer and implement process adjustments real-time

Outcome:

- Flaw identification of 98.2% based on almost 2000 melt layers
- Flaw reduction from 87% to 99%
- DLA Phase II SBIR award



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Multi-Location Beam Interrogation

Objectives:

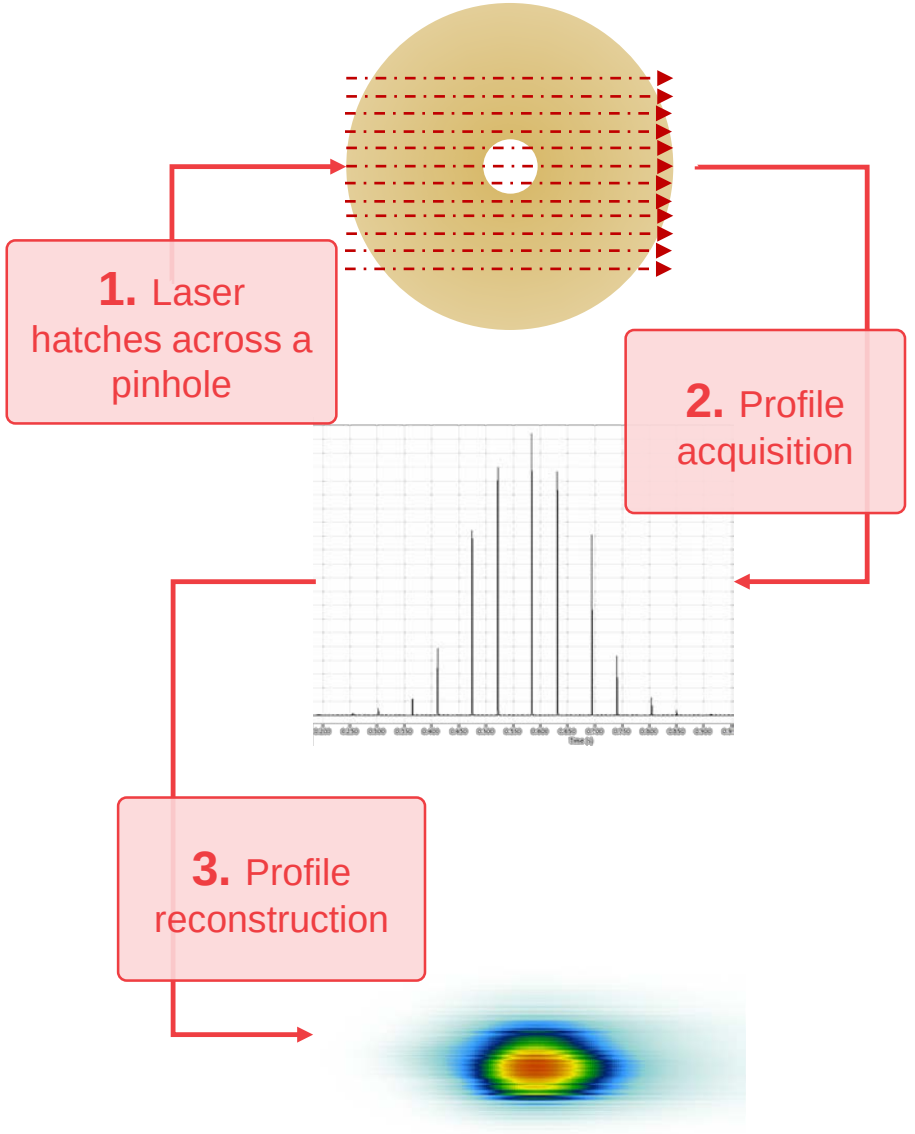
- Conceptualize, design, and configure a laser beam interrogation apparatus
- Evaluate performance, durability, and applicability inside a L-PBF machine

Solution:

- Photodiode and pinhole-based solution using the built-in capability of L-PBF machines to raster the laser across the build plane

Outcome:

- Pinhole survivability testing and design optimization to withstand laser passes at 100W
- Comparable spot measurement to single-location sensors
- Patent application



Centers & Consortia

EWI
We Manufacture Innovation

AMC: Overview

Accelerating and advancing the manufacturing readiness of metal AM technologies

Secondary Objectives:

- Platform for collaboration across global industry, academia and government entities.
- Execute group sponsored projects focused on addressing pre-competitive AM challenges
- Partner on government funding opportunities
- Forum for discussion/shaping AM roadmaps

Members:

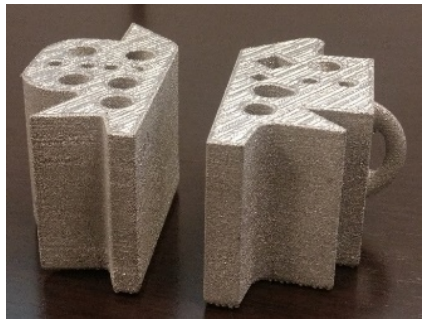
- 55 total (full/non-profit/supplier/research partner)

Projects:

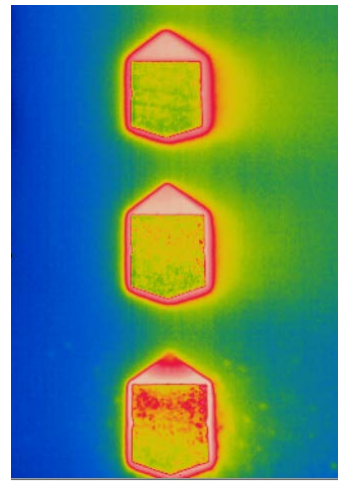
- 6-7 projects in a given year; 12-month timelines

Additive Manufacturing Consortium
Operated by EWI

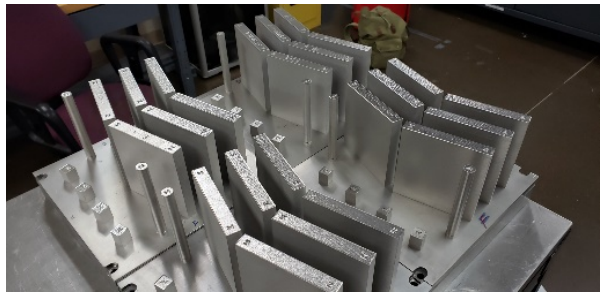
AMC: 2018 Projects

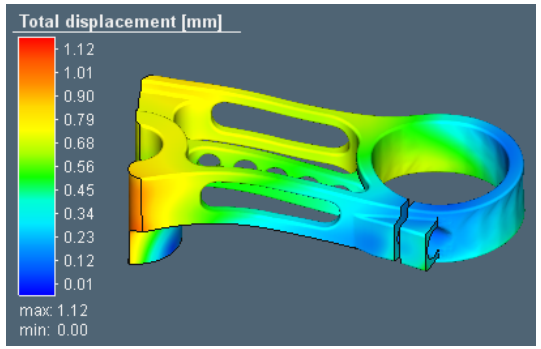


1. Evaluation of Post Process Techniques for AM
2. Phase II: In-Process Monitoring & Defect Rectification



3. IN 625 and IN 718: Relating Microstructure to AM Properties
4. DED Multi-material/Repair
5. Comparison of Commercially Available AM Simulation Tools
6. Multi-Process AM for Stainless Steel





per membership and sponsorship agreement terms

AMC: 2019 Projects

Additive Manufacturing Consortium
Operated by EWI

1. Continuing further testing on current Inconel projects
2. Evaluation of powder property measurement techniques
3. Assessment of new metal AM technologies
4. Feature wise parameter development L-PBF
5. Evaluation of commercial in-situ monitoring systems for L-PBF
6. Evaluation of NDE techniques for complex AM parts
7. Phase II: Evaluation of commercially available surface finishing technologies

ASTM AM CoE:

Bridging standards development with R&D to better enable efficient development of standards, education and training, certification, and proficiency testing programs

Facilitator of R&D, standards development, and enabling qualification & certification

Build industry consortia and work with them to identify and advance standards

In addition to R&D, develop education and training resources and tools

Provide expertise in conducting R&D for standards in the aerospace and aviation fields

Global perspective on conducting R&D for standards for AM

THANK YOU

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