Science-based Acceleration of the Full Value Stream for Metal Additive Manufacturing: Expedited AM Powder Development

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AMES, ORNL, KCNSC, SNL, ANL & Industrial Partners
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U.S. DEPARTMENT OF ENERGY

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Overview

Project Title: Science-based Acceleration of the Full Value Stream for Metal Additive Manufacturing: Expedited AM Powder Development

Timeline:

Project Start Date: 12/01/2019

Budget Period End Date: 09/30/2021

Project End Date: 09/30/2021

Barriers and Challenges:

- Materials Discovery
- Materials Compatibility
- Validation and Demonstration

AMO MYPP Connection:

- 3.1.4 Materials for Harsh Service Conditions
  Target 4.2: Accelerate the process of materials discovery by 50% to improve performance in selected applications/materials classes
  Target 4.3: Achieve performance-based cost parity for the manufacture of alternative materials and parts for use in harsh service conditions
- 3.1.6 Additive Manufacturing
  Target 6.1: Demonstrate AM components whose physical properties and cost/value outperform selected conventionally produced parts by 20%

Project Budget and Costs:

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$8,120,000	$1,100,001	$9,220,001	11.9%
Approved Budget	$8,120,000	$1,100,001	$9,220,001	11.9%
Costs as of 3/31/19	$1,208,125	$33,815	$1,241,940	2.7%

Project Team and Roles:

- AMES (Lead): Project management, alloy design & selection, characterization, sample & powder production
- ORNL: Ni-base superalloy melting scans & AM builds, verification of AM processing method & parameter selection
- SNL: Alloy design input for high entropy alloys (HEA), HEA melting & AM builds, characterization
- KCNSC: Al alloy melting scans & AM builds, characterization
- ANL: APS internal porosity measurements of AM powders
- Industrial partners (in-kind): Economic analysis of technology impact, input to target property metrics & key applications, AM processing of samples, characterization, AM powder production

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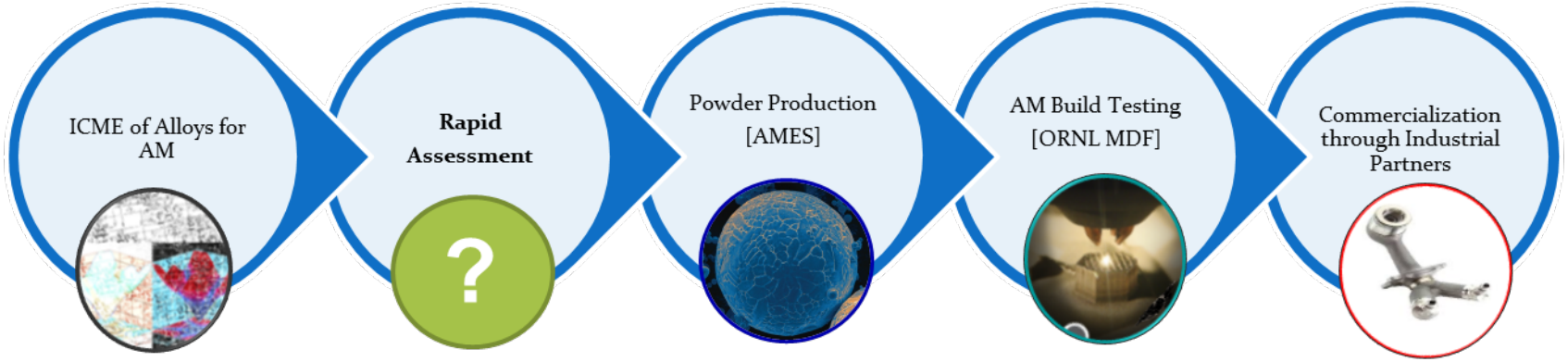
Project Objective

Development of a rapid, science-based approach to alloy design for AM.

- Potential to revolutionize efficiency in manufacturing requires optimizing metal alloys for AM
  - Rapid solidification processing
- Reduce the time for alloy design iterations
  - Developing knowledge-base tools for alloy design



(Science-based Acceleration of the Full Value Stream for Metal AM)

Technical Innovation

- Alloy design for AM
  - Thermodynamic & solidification modeling
    - Improve build outcomes (e.g., reduce cracking issues, undesirable metastable phases, volatile losses)
  - Rapid assessment of prototype alloys
- Design process plus three new alloys will enable AM for aerospace, energy, defense, & transportation

High Strength Al Alloys	Next Generation Ni-base Superalloys	High Entropy Alloys
• Transportation • AMES • KCNSC	• Aerospace & Energy • AMES • ORNL	• Defense & Energy • AMES • SNL

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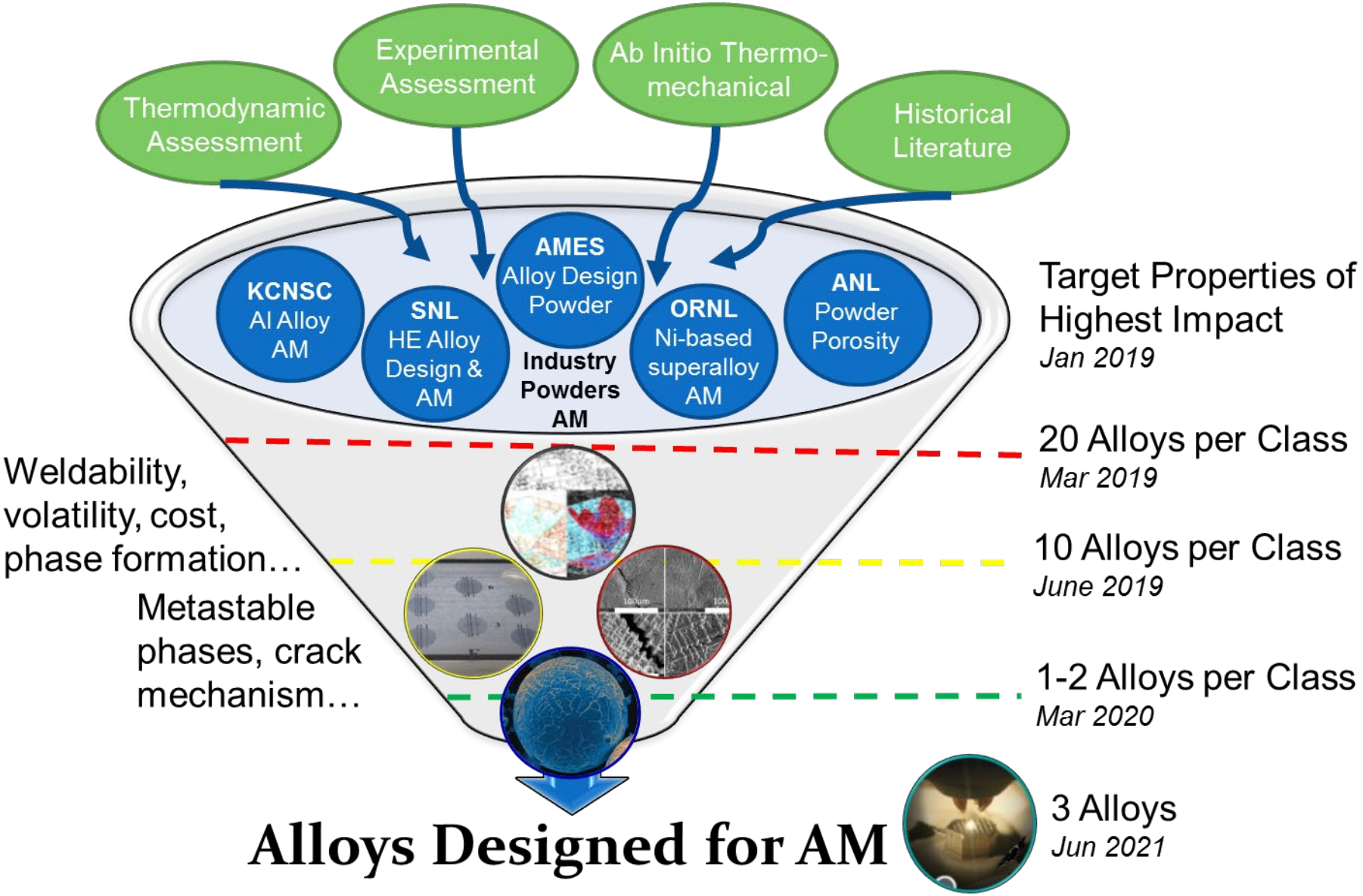
Technical Approach



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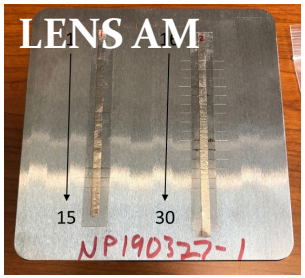
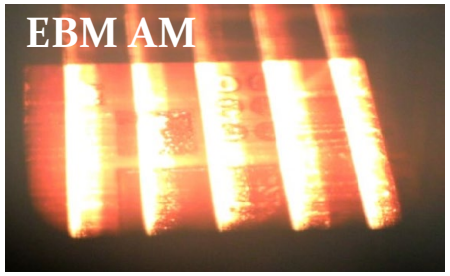
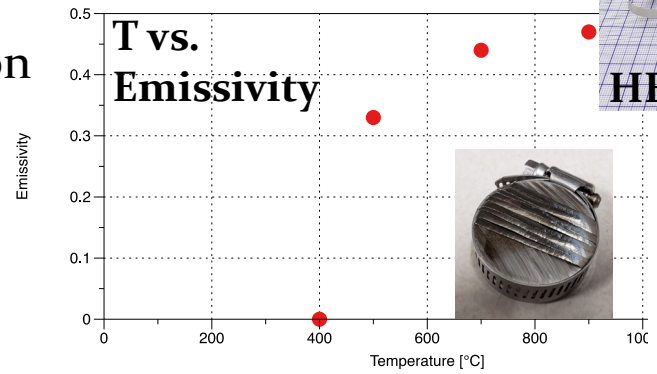
Results and Accomplishments

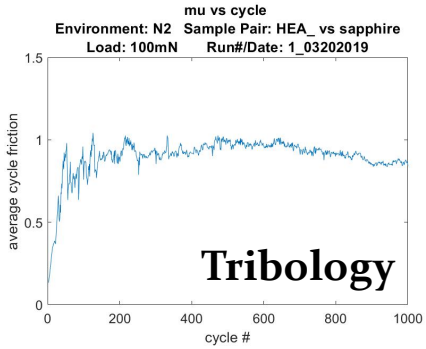
- Milestones:
  - Performance targets & criteria
  - 20 alloys defined in each class
    - Phases, Scheil solidification, lattice mismatch, volume change
- Results:
  - Thermodynamic & electronic models
  - Initial samples of baseline alloys
  - Hot cracking susceptibility testing
- Further Work:
  - Down-selection of alloys
  - Powder production
  - AM builds & characterization

Alloy	Target 1	Target 2
Al	YS of 500MPa @ RT YS of 400MPa @ 180C Fatigue Strength 250MPa HT Fatigue >10^7 cycles 180MPa @ 180C Elongation >10%	YS of 300MPa @ RT YS of 200MPa @ 300C Fatigue Strength 150MPa HT Fatigue >10^7 cycles 150MPa @ 300C Elongation >10%
Ni	TS 143ksi YS 121ksi Elongation 6-7% Operating T 1900F Weldable, TBC, lower Co	TS >150ksi YS >130ksi Elongation >14% Operating T 1300°F Weldable, TBC
HEA	YS 1GPa @ RT YS 0.8GPa @ 800C TS 1.2GPa Elongation >10% @ RT	YS 2GPa @ RT YS 1.6GPa @ 800C Elongation >10% @ RT-800C









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Transition (beyond DOE assistance)

- Input to alloy targets
- Economic analysis of impact
- Improved powder production
- AM builds & characterization by OEMs