Powder Synthesis and Alloy Design for Additive Manufacturing

CPS Agreement Number: 32036, WBS #2.1.013
Ames Laboratory/Oak Ridge National Lab—Manufacturing Demonstration Facility
October 1, 2016 to June 30, 2019

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Overview

Timeline

- Project Start: October 2016
- Projected End: June 2019, with NCE.
- Project 100% complete

Budget	FY 17	FY 18	FY 19
DOE Funded	$2.0M	$3.0M	
Project Cost Share	$0M	$0M	

Alignment with AMO MYPP Goals

- 3.1.4 Materials for Harsh Service Conditions
  Target 4.3: Achieve performance-based cost parity for the manufacture of alternative materials and parts for use in harsh service conditions. **Develop tailored powders for AM for use in high-temperature, high-pressure, high-value applications such as power generation turbine blades.**
- 3.1.6 Additive Manufacturing
  Target 6.1: Demonstrate AM components whose physical properties and cost/value outperform selected conventionally produced parts by 20%

Barriers

- Inconsistent AM powder feedstock quality and excessive cost.
- Need for alloys designed to mitigate build cracking and benefit from AM processing.

Partners

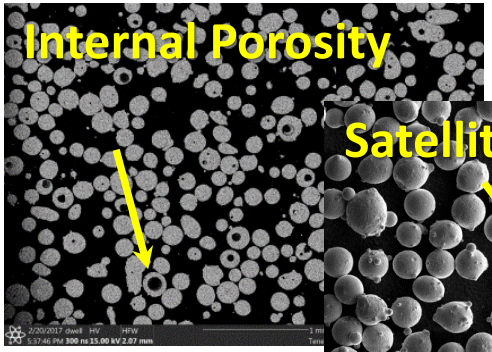
- Ames Laboratory (lead): managing the project, performing alloy design and sample characterization, improving the gas atomization process for AM feedstock powders, and producing powders of the improved alloy designs in-house
- Oak Ridge National Laboratory's Manufacturing Demonstration Facility: providing input to the alloy design, assisting in AM feedstock specification and performing AM builds of the produced powders

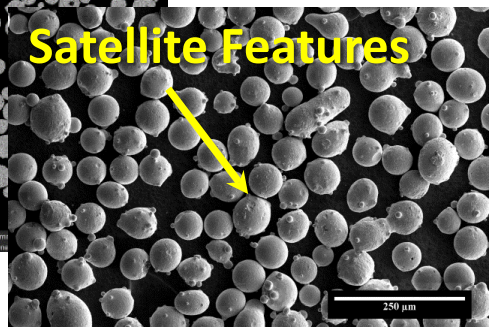
Project Objective

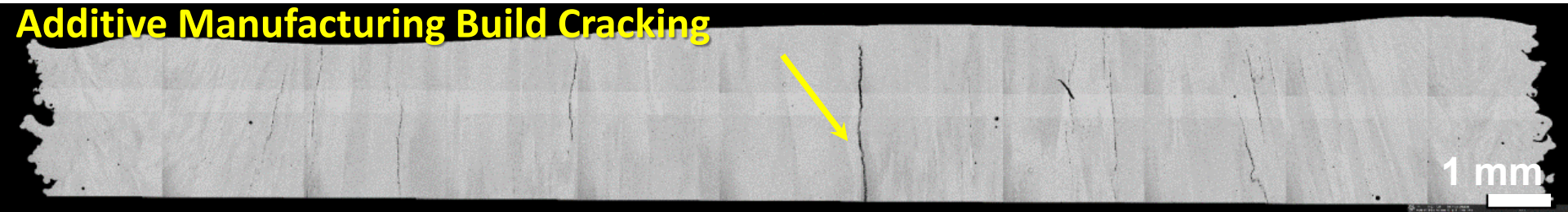
- Additive manufacturing (AM) promises to change the game in metal and alloy component production
  - Ultimate design agility, rapid prototyping, mold fabrication
  - Increased complexity for part and system designs
- Today's metallic AM parts include:
  - Segregation, residual porosity & stress
  - Unwanted inclusions/precipitates
  - Limitations of conventional alloy compositions
- Realization of AM process potential requires ideal powder feedstocks
  - Reasonable cost
  - Compositions designed for AM processing
  - Spherical, smooth/flowable, low porosity & oxidation

Technical Innovation

- Gas atomization = potential low cost method of mass production for AM powders
- Currently suffers from:
  - Low yield (tight size range limits)
    - Need powder size separation
    - Off-size inventory/reverb/waste
  - Internal porosity (powders > 50µm, EBM-AM)
  - Reduced flowability (satellite powder features)
  - Surface impurities (excessive oxidation)
  - Available powders of conventional alloys, not designed for AM melting & solidification conditions (poor "weldability")

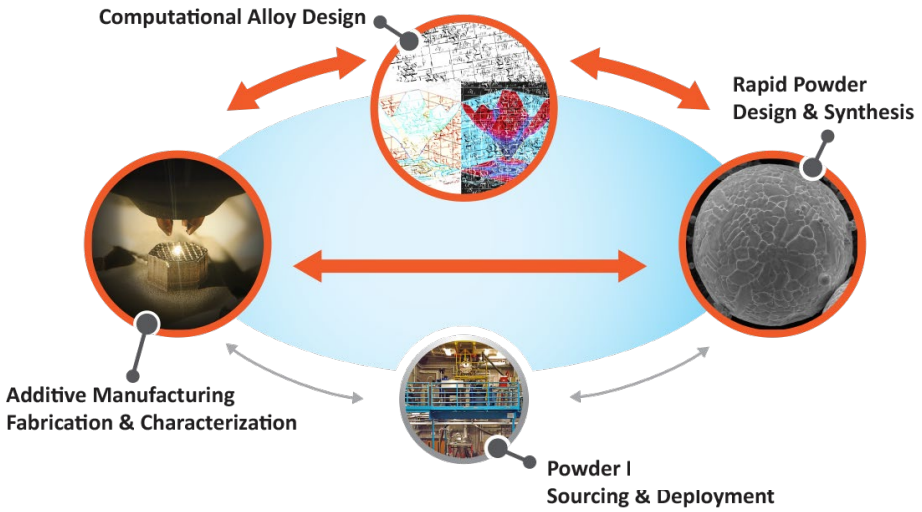






Technical Innovation

- Address AM powder feedstock issues via:
  - Advancing gas atomization technology
    - Improve powder size yield (increase efficiency, lower production cost)
    - Increase smooth spherical shape uniformity (improve flowability)
    - Suppress internal porosity (reduce persistent pores that resist HIP)
    - Lower powder oxidation (improve ductility & fatigue performance)
  - Designing metal alloys for AM
    - Thermodynamic & solidification modeling (improve build microstructure and performance)

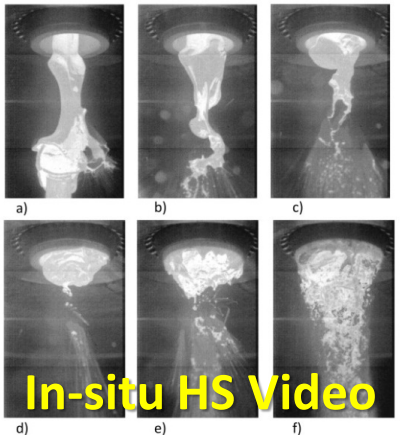


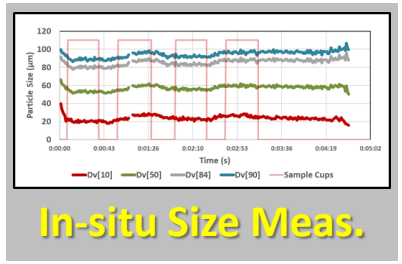
Technical Approach

- Expanded gas atomized powder making efficiency and quality for AM processing
  - Utilized AMES atomization capability, in-situ process monitoring and system customization, unique within atomization research community world-wide.
  - Performed “pilot-scale” atomization runs.
  - Correlated atomization results with AMES CFD multi-phase flow 2-D & 3-D modeling.

Unknown/Risk: explored limits to improved atomization efficiency & powder quality

Based on AMES extensive recent licensing experience, activated research partnership with leading powder producer on new alloy.



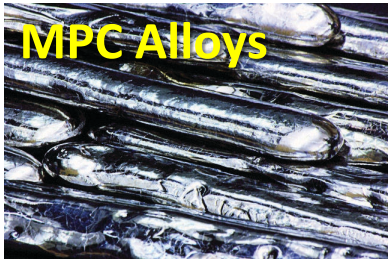


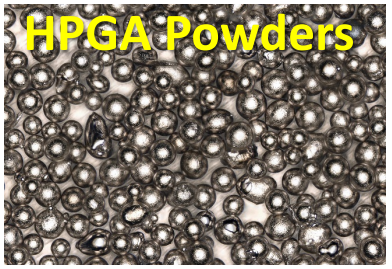
Technical Approach

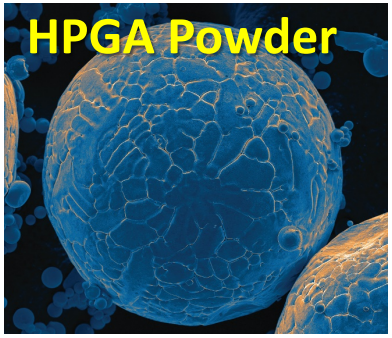
- Developed effective alloy design principles and methodology for AM feedstock powders
  - ORNL shared AM experience on target alloy for high temperature/strength (Mar-M-247)
  - Used AMES alloy design expertise to modify
  - AMES Materials Preparation Center made precision alloys for tests and atomization runs
  - ORNL made AM builds with AMES alloy powder and commercial powder batch of AMES alloy

Unknown/Risk: investigated if Mar-M-247 could be made AM-compatible with modification.

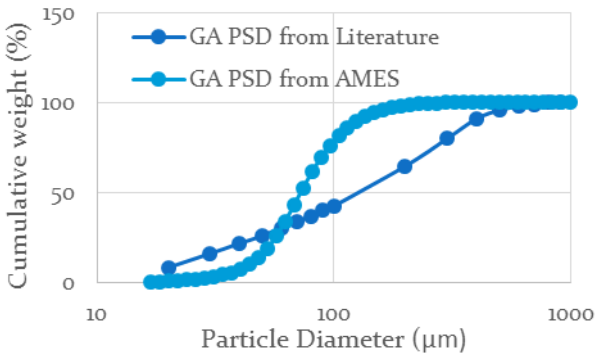
Developed ORNL & AMES research partnership for rapid AM alloy re-design and build testing.



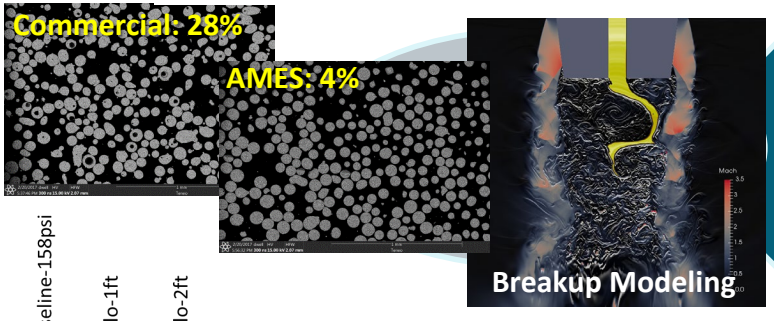




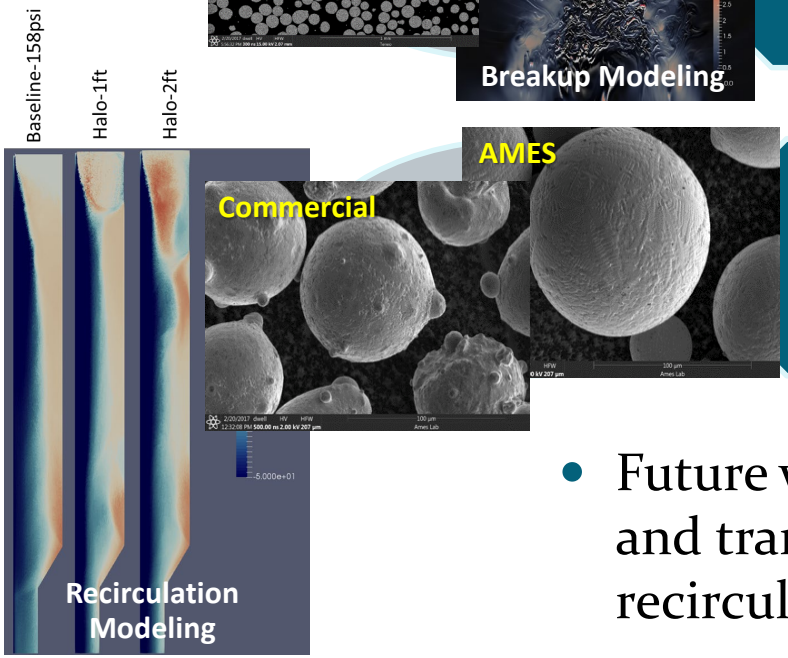
Results on Powder Making Efficiency and Quality for AM



Tripled (3X) typical powder yield for EBM-AM via gas atomization utilizing in-situ process sensor for powder size



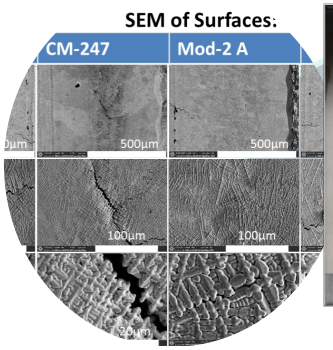
High speed video of atomization spray comparison for verification of melt break-up (2-D/3-D) modeling & simulation, lower energy from models used to reduce internal porosity

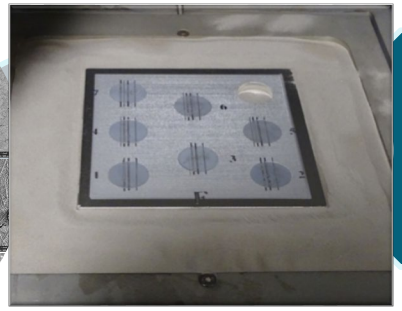


Spray chamber flow modeling used to minimize powder satellites

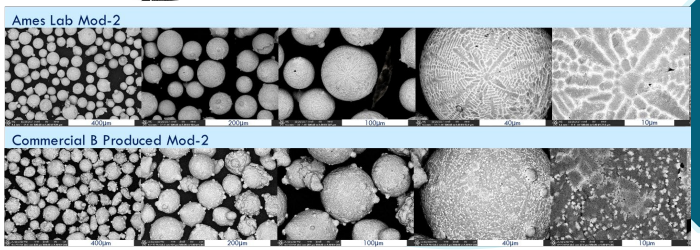
- Future work: Correlation of models with experiment and transition to full 3D models for break-up and recirculation.

Results on Alloy Design Methodology for AM Powders



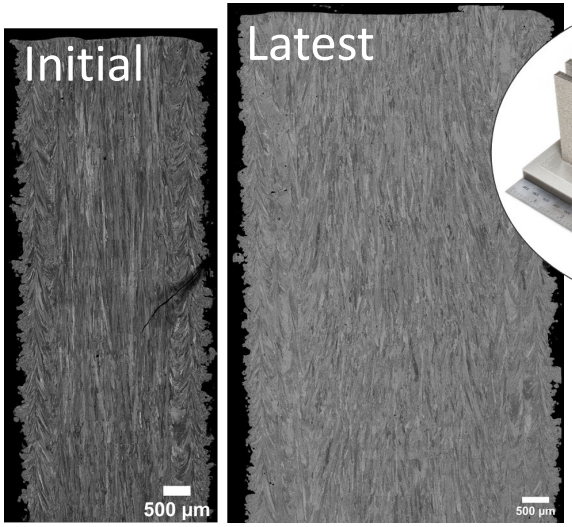


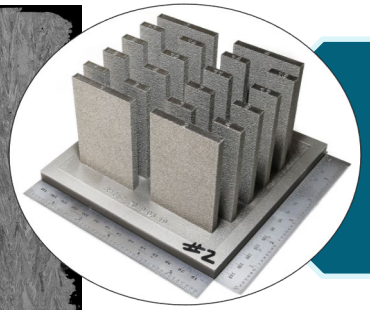
Thermodynamic and solidification modeling compared to multi-pass (laser & e-beam) solidification microstructures



2nd generation modified (Mod-2) alloy powder produced

(by AMES & industry partner)





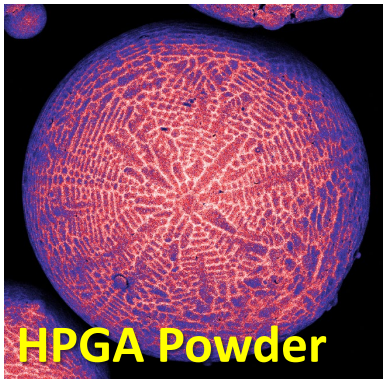
AM builds of Mod-2 alloy powders characterized

(microstructure and strength testing)

- Future work: High temperature mechanical testing of builds from Mod-2 powder.

Transition (beyond DOE assistance)

- Results encourage American competitiveness in critical advanced manufacturing technologies
- Involving U.S. supply chain for additive manufacturing
- Powder producers & AM users enabled
  - Increased production efficiency/lower costs
- Developing IP to promote CRADAs
  - Reserving new technologies for further development by US industry partners



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