Powder Synthesis and Alloy Design for Additive Manufacturing

Contract No. 2.1.0.13, CPS Agreement No. 32036
Project Team: Ames Lab & ORNL-MDF/Praxair
October 1, 2016 to September 30, 2018

Iver E Anderson, Ames Laboratory (USDOE), Iowa State University

U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
July 17, 2018

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Overview

Timeline

- Project Start date October 2016
- Projected End date September 2018
- Project 85% complete

Budget

	FY 17 Costs	FY 18 Costs
DOE Funded	$2.5M	$2.5M
Project Cost Share	$0M	$0M

Barriers

- AM powder feedstock quality and high cost
- Advanced alloys not designed to be beneficial for AM processing, e.g, build cracking problems.

Partners

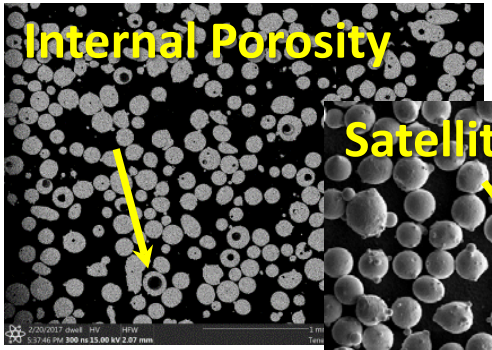
- Ames Laboratory is the lead lab: managing the project, performing alloy design and sample characterization, improving the gas atomization process for AM feedstock powders, and producing the improved alloy design powders in-house
- Oak Ridge National Laboratory's Manufacturing Demonstration Facility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

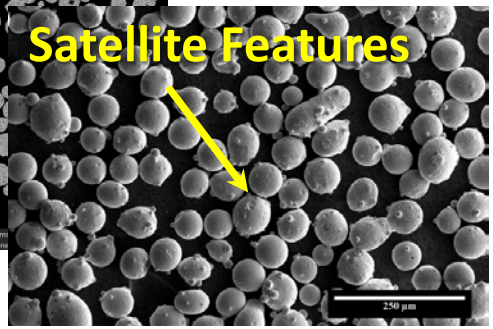
Project Objective

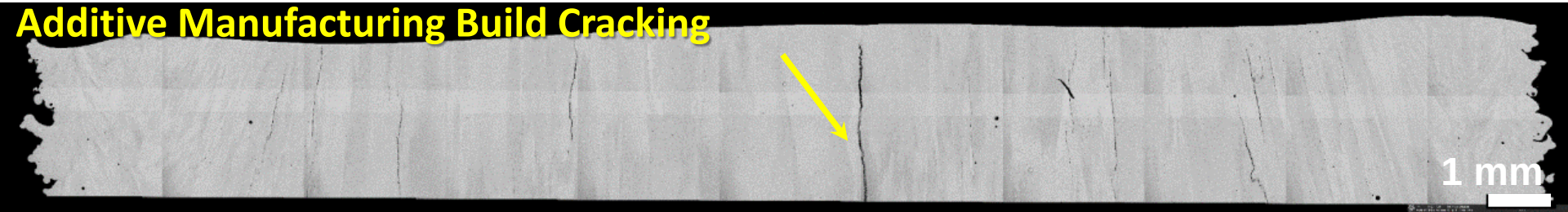
- Additive manufacturing (AM) promises to change the game in metal and alloy component production
  - Ultimate agility, rapid prototyping, mold fabrication
  - Increased complexity for part and system designs
- Today's metallic AM parts include:
  - Excessive porosity
  - Unwanted inclusions/precipitates
  - Deviation from desired final composition
- Realization of AM process potential requires ideal powder feedstocks
  - Reasonable cost
  - Compositions designed for AM processing
  - Spherical, low porosity

Technical Innovation

- Gas atomization = potential low cost method of powder production
- Currently suffers from:
  - Low useful yield
  - Need for size separation
  - Internal porosity
  - Reduced flowability (satellite powder features)
  - Surface impurities (extra oxidation)
  - Poor build microstructures and mechanical properties due to alloys not designed for AM melting & solidification conditions

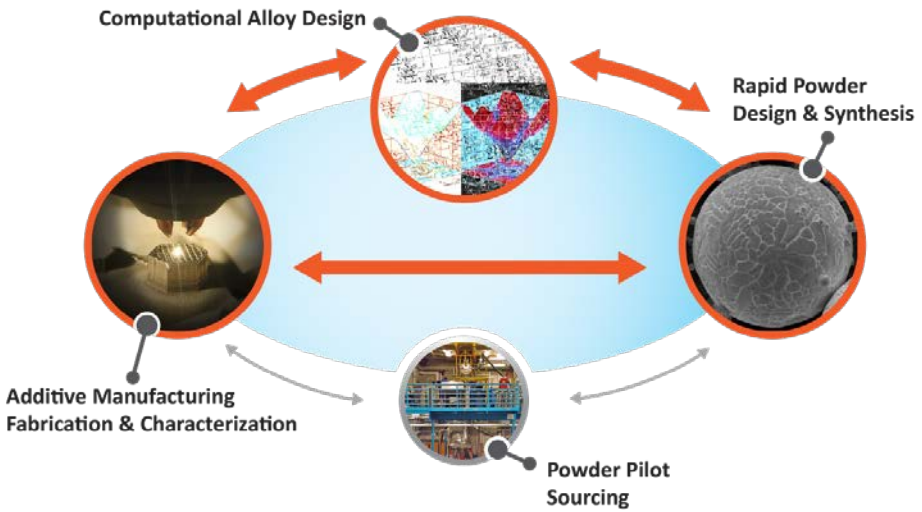






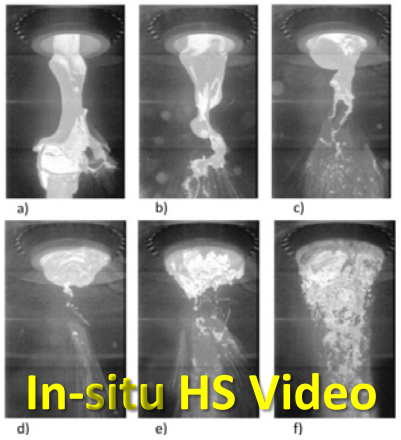
Technical Innovation

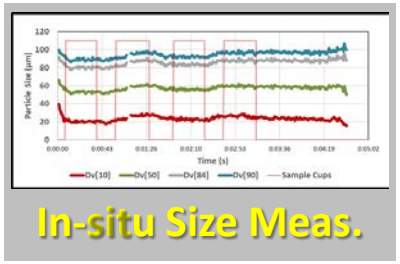
- Address AM powder feedstock issues via:
  - Advancing gas atomization technology
    - Improve powder size yield (increase efficiency, lower $$)
    - Increase spherical shape uniformity (improve performance)
    - Suppress internal porosity (improve performance)
    - Lower powder oxidation (improve performance)
  - Designing metal alloys for AM
    - Thermodynamic & solidification modeling (improve performance)



Technical Approach

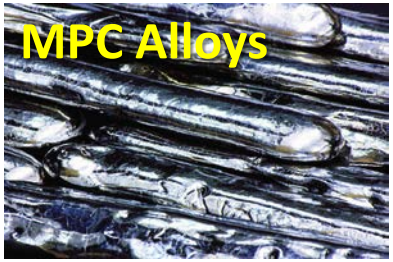
- Expand gas atomized powder making efficiency and quality for AM processing
  - AMES “pilot-scale” atomization experiments
  - AMES CFD multi-phase flow analysis correlation
  - AMES internal atomization capability, in-situ process monitoring and customization is unique within the atomization research community world-wide
  - Unknown/Risk: extent gas atomization efficiency & quality can be improved?
  - AMES has extensive past licensing experience and research partnerships with powder producers

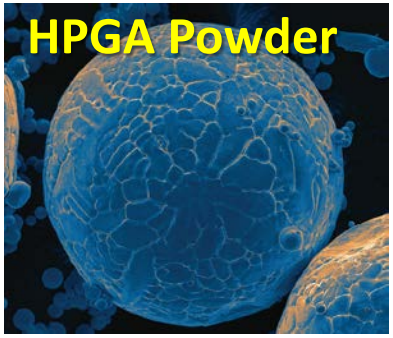




Technical Approach

- Develop effective alloy design principles for AM feedstock powders
  - ORNL AM experience across alloy systems
  - AMES metallic alloy design expertise
  - AMES Materials Preparation Center for precision master alloys
  - ORNL makes AM builds from AMES designed & produced powder
  - Unknown/Risk: if Mar-M-247 is not AM compatible even with modification, an alternate alloy will be selected with similar tolerance for extreme environments
  - ORNL & AMES research partnerships for rapid alloy commercialization

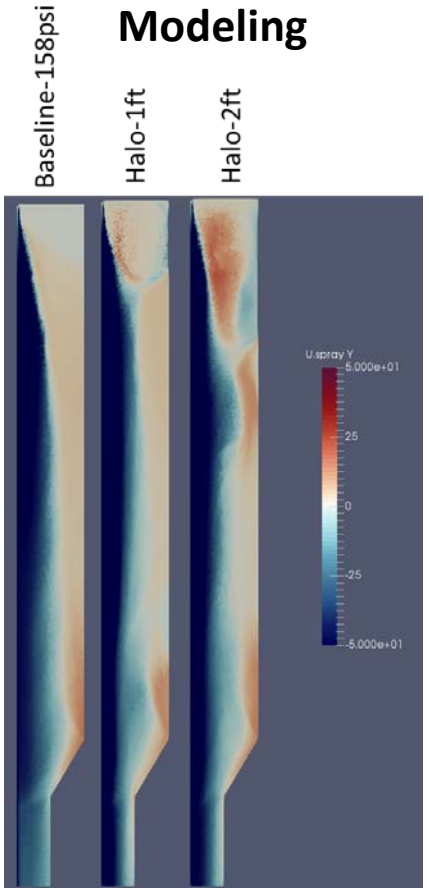




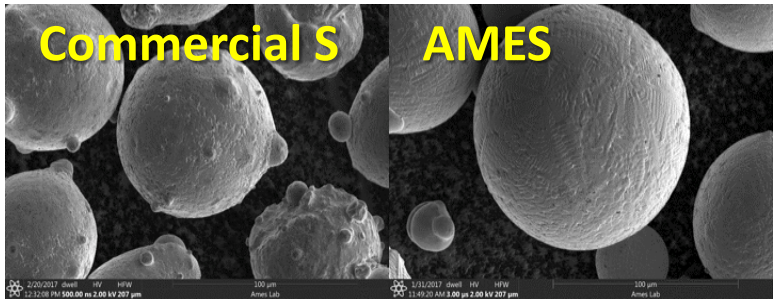
Results and Accomplishments

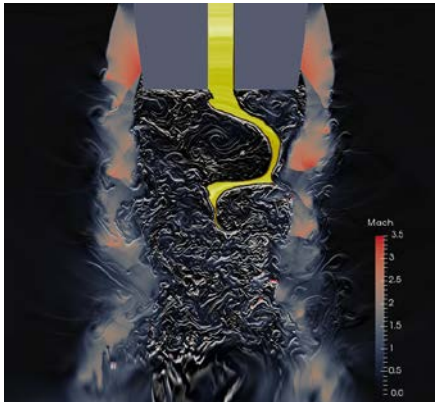
- Task 1 completed: in-operando process sensor demonstrated, melt break-up simulated, spray chamber modeled/expanded, minimized powder satellites and internal porosity, achieved more than 3X desired size yield.
- Task 2 completed: commercial powder & AM build characterization, 2 alloy generations designed & powders produced of both, successful AM builds of 2nd generation alloy, screened additional 2nd gen. supply, ordered large industrial batch of 2nd gen. alloy.

Recirculation Modeling



Satellite Reduction





Gas/Liquid Breakup Modeling

- Future work: Correlation of models with experiment and transition to fully 3D models for break-up and recirculation, mechanical testing of full height builds with 2nd generation powder.

Transition (beyond DOE assistance)

- American competitiveness in critical technologies
- U.S. supply chain for additive manufacturing
- Powder producers & AM users
  - Increased efficiency & lower costs
- Licensing of IP, SPPs, CRADAs
  - Pre-competitive/enabling tech further developed for commercial production

PRAXAIR SURFACE TECHNOLOGIES

ARCONIC

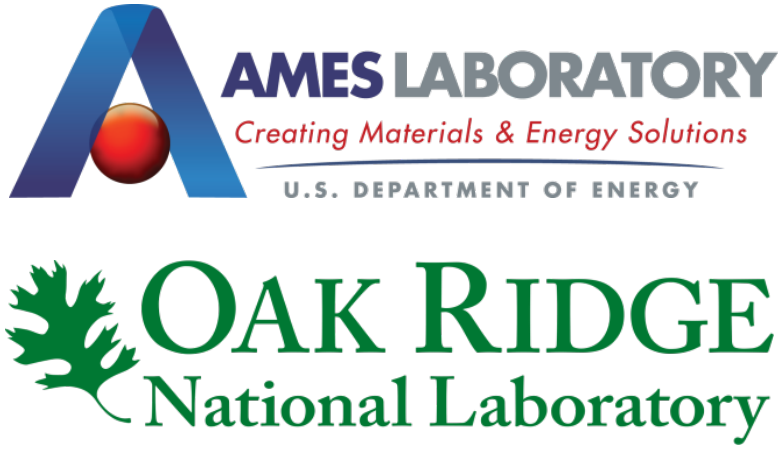
CARPENTER

oerlikon

AMPAL INC.

ISM

Questions?


AMES LABORATORY
Creating Materials & Energy Solutions
U.S. DEPARTMENT OF ENERGY
OAK RIDGE
National Laboratory