Powder Synthesis and Alloy Design for Additive Manufacturing

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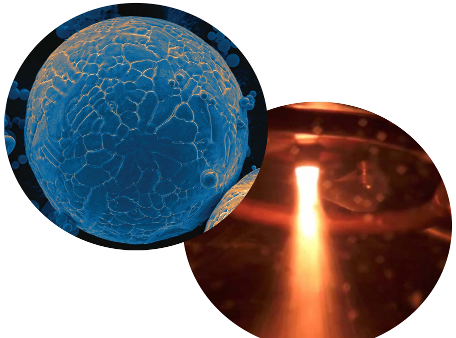
Project Objective

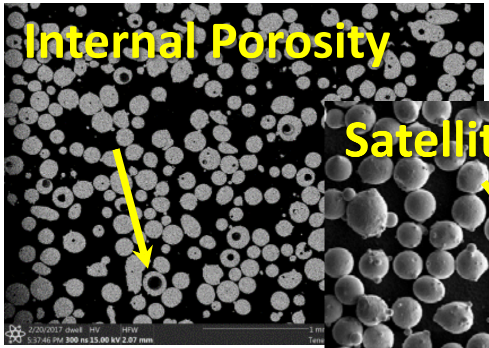
- Additive manufacturing (AM) promises to change the game in metal and alloy component production
  - Ultimate agility, rapid prototyping, mold fabrication
  - Increased complexity for part and system designs
- Today's metallic AM parts include:
  - Excessive porosity
  - Unwanted inclusions/precipitates
  - Deviation from desired final composition

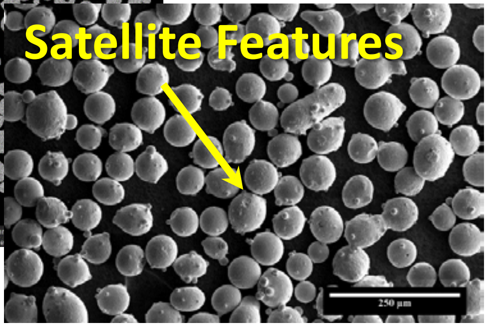
- Realization of AM process potential requires ideal powder feedstocks
  - Reasonable cost
  - Compositions designed for AM processing
  - Spherical, low porosity

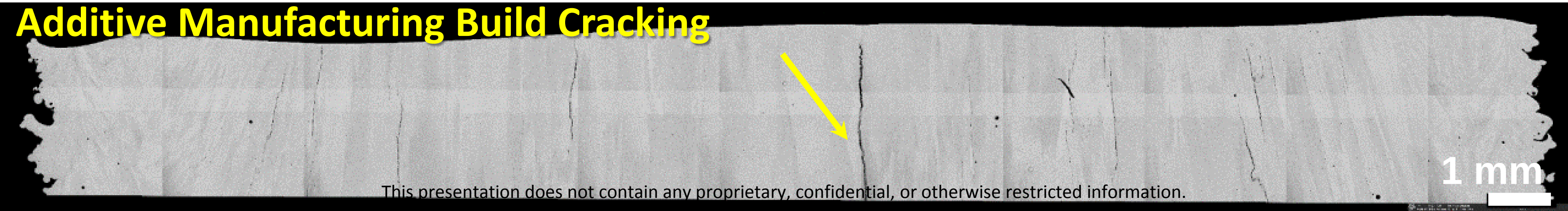


Technical Innovation

- 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

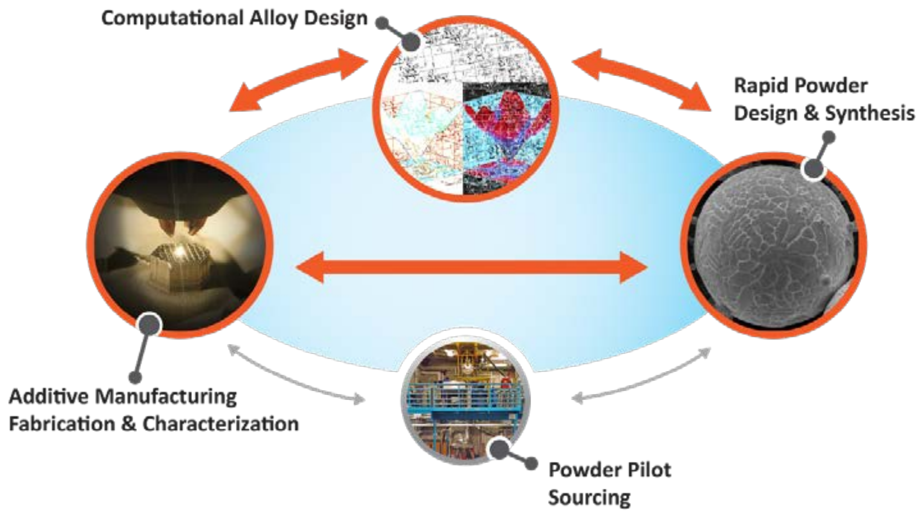






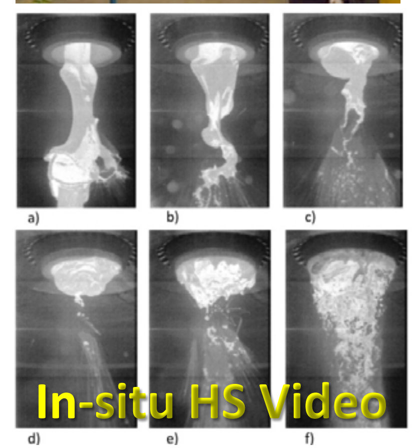
Technical Innovation

- 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)



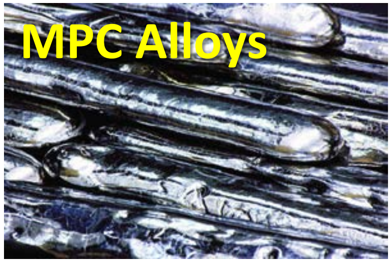
Technical Approach

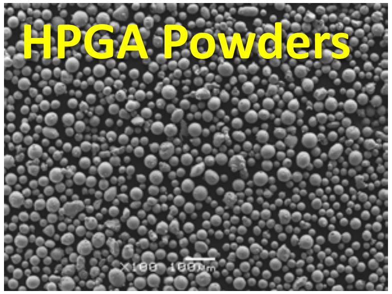
- Expand gas atomized powder making efficiency and quality for AM processing
  - AMES “pilot-scale” atomization experiments
  - AMES CFD multi-phase flow analysis correlation
  - AMES internal atomization capability, in-situ process monitoring and customization is unique within the atomization research 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





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.

USM

Measure of Success

- Additive Manufacturing market worth $4.1B in 2014; estimated to be $17B by 2020, (20%/yr) [Wohlers Report]
- Many companies going into production with metal AM:
  - Aerospace: GE, Pratt & Whitney, Rolls-Royce, Avio Aero, NASA, Aerojet Rocketdyne, Airbus,...
  - Medical: Exactech, Lima, Adler Ortho,...
  - Defense: Armed Forces, UAVs,...
- Enabling technology for U.S. metal AM competitiveness
  - Reducing overall costs
  - Improving energy efficiency (material & production)
  - New alloys allow improved AM part performance
  - New technologies will proceed from these early stage developments

Project Management & Budget

- FY16-FY17: October 2016 to December 2017

Milestones	End Date
Improve Powder Size Range Yield for AM	6/30/17
Produce AM Builds from 1st Generation Alloy	6/30/17
Further Improve Powder Size Range Yield for AM	12/31/17

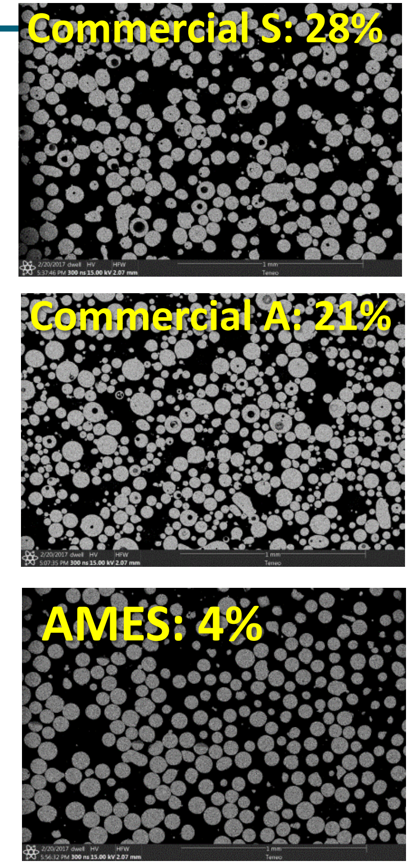
Task ID	Description	Estimated Budget
T0	Project Management	$100K
T1	Gas Atomization Processing Improvements	$1,925K
T2	Improved Alloy Powders for Sever Environment Service	$2,625K
T3	Promotion of Team Interaction	$150K
T4	Acceleration of Technology Transition	$200K

Total Project Budget	
DOE Investment	$5,000K
Cost Share	$0K
Project Total	$5,000K

Results and Accomplishments

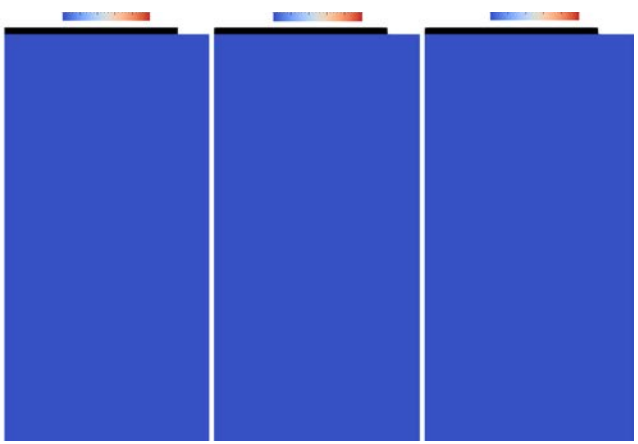
- Task 1 completion: in-situ process sensor, melt break-up simulation, spray chamber flow model, minimize powder satellites and internal porosity
- Task 2 completion: commercial powder & AM build characterization, 1st gen. modified alloy powder produced

Internal Porosity

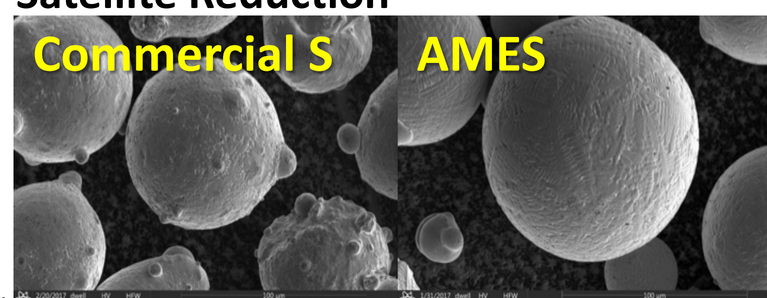


In Situ HS Video

Gas/Liquid Breakup Modeling



Satellite Reduction



- Future work: Correlation of models to experimental data and 2nd alloy design iteration