DOE Funding Opportunity DE-FOA-0001817

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Company Highlights

BWXT is one of the world's most prolific nuclear technology innovation companies and the sole manufacturer of naval nuclear reactors for U.S. submarines and aircraft carriers.

6,250
highly skilled employees

$1.8 billion USD
in 2018 revenues

11
major manufacturing facilities totaling 3.8 million square feet

60+
years manufacturing naval nuclear components and reactors

300+
commercial nuclear steam generators manufactured

1.5 million+
Canada Deuterium Uranium (CANDU) fuel bundles provided

14
U.S. Department of Energy laboratories, environmental cleanup projects and NASA sites

8,000+
fuel elements delivered to U.S. national laboratories, universities and international customers

Our History

We have been at the forefront of the commercial nuclear power generation and government nuclear industries for decades, achieving an impressive number of firsts along the way.

HISTORY OF INNOVATION

1850s

Our heritage dates back to the invention of the water tube boiler by Stephen Wilcox, who later founded The Babcock & Wilcox Company.

NUCLEAR FLEET

1950s

Our naval nuclear lineage began with the USS Nautilus, the world's first nuclear-powered submarine.

EXPANDING CAPABILITIES

2000s

We completed key acquisitions and a successful spin-off of our power generation business while developing new, advanced technologies.

BWXT, A Complete Life Cycle Provider – What We Do

Advanced Technologies
- Advanced Reactors Design
- Developmental Testing
- Manufacturing Development Including Additive
- Radioisotope Development

Commercial Nuclear Fuel
- CANDU Fuel
- Fuel Handling & Engineered Solutions
- Nuclear Non-Proliferation

Commercial Nuclear Components
- Steam Generators
- Heat Exchangers
- Reactor Vessels

Complex Operations Management
- Nuclear Facilities & Operations Management
- Nuclear Materials Management
- Environmental Safety & Health Management

Environmental Management
- Waste Management
- Facility Decontamination, Decommissioning & Demolition
- Remediation & Restoration

Laboratory Services
- Failure Analysis
- Nondestructive Evaluation & Inspection Systems
- Strategic Materials

Naval Nuclear Propulsion
- Design Engineering
- Precision Manufacturing
- Nuclear Fuel

Nuclear Services
- Steam Generator Services
- PWR Heat Exchanger Services
- Reactor Services

Radiochemistry
- Medical Isotope Production
- Research & Development
- Processing, Packaging & Delivery Services

Research Test Reactors
- Fuel Plates & Target Manufacturing
- Fuel Powder
- Low-Enriched Uranium Fuel Development

Space Applications
- Nuclear Thermal Propulsion
- Reactor Design & Fuel Development
- Ground Testing

Funding Opportunity: DE-FOA-0001817

- **FOA Title:** U.S. Industry Opportunities for Advanced Nuclear Technology Development
- **Topic:** Establishment of an integrated, advanced manufacturing and data science driven paradigm for advanced reactor systems
- **Award (ID) Number:** DE-NE0008744
- **Awardee:** BWXT Nuclear Energy, Inc.
- **Awardee DUNS #:** 829891394
- **Collaborator:** Oak Ridge National Laboratory / Manufacturing Demonstration Facility (FFRDC)

Arcam Spectra H Installed at ORNL-MDF

DE-FOA-0001817 - Acknowledgements

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  - Brian Barger
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  - Travis Fritts*
  - Chris Folmar
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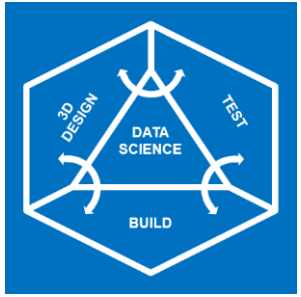
  - Jason Allen
  - Xiang (Frank) Chen
  - Ryan Duncan
  - Betsy Ellis
  - Michael Kirka
  - Kory Linton
  - Vincent Paquit
  - Xin Sun

*Co-located at ORNL / MDF

Objectives



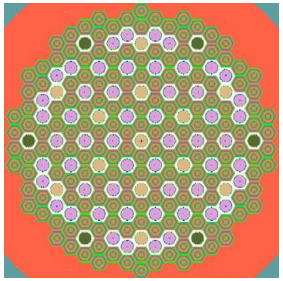
ID4BT
- Rapid Development Paradigm
- Technology Driven
- Enabling the Commercialization of High Power Dense Nuclear Designs

Reactor Design
- GEN IV
- Compact
- Cost Effective
- Inherently Safe

Advanced Materials
- Technology Leap
- Not AM Today
- Increased Safety Margins

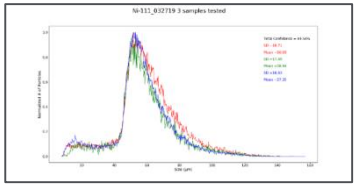
Additive Manufacturing
- Unique Geometries
- Improved Thermal Energy Management
- Customized Design

ID^{4}BT = Integrated 3D Design, Build, Test, & Data Science

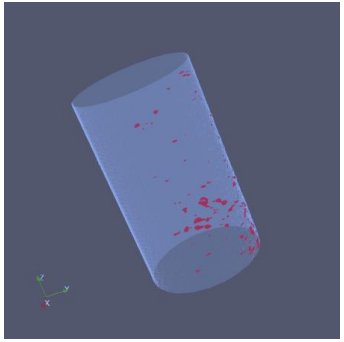


Integrated Design
- Requirements Development
- Mechanical Design
- Core Physics
- Thermal Analysis
- VHTR Concept
- UHTR Concept

Build
- AM HAST® X
- AM Mo Alloys



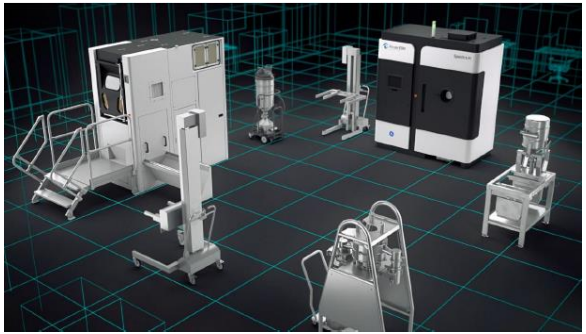
Test
- Chemical Analysis
- Mechanical Tests
- Powder Characterization



Data Science
- In-situ monitoring
- 3D part reconstruction

Why Electron Beam Additive Technology?

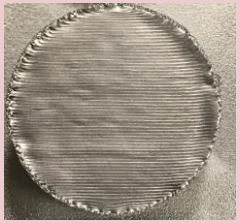
- The benefits of EBM over other AM technologies:
  - Low risk of contamination due to processing in a vacuum
  - Pre/Post heating allows builds to be performed at elevated temperatures
  - Accurate and fast beam location control
  - Precision control over processing parameters and scan strategy
    - » Precise pre/post heating during builds
    - » Manipulate grain microstructure (equiaxed vs columnar)
- Arcam Spectra H
  - 6kW beam power
  - 250mm x 250mm x 430mm build volume
  - BWXT has the first operational unit in the U.S.



Hastelloy® X Build Overview – Spectra H

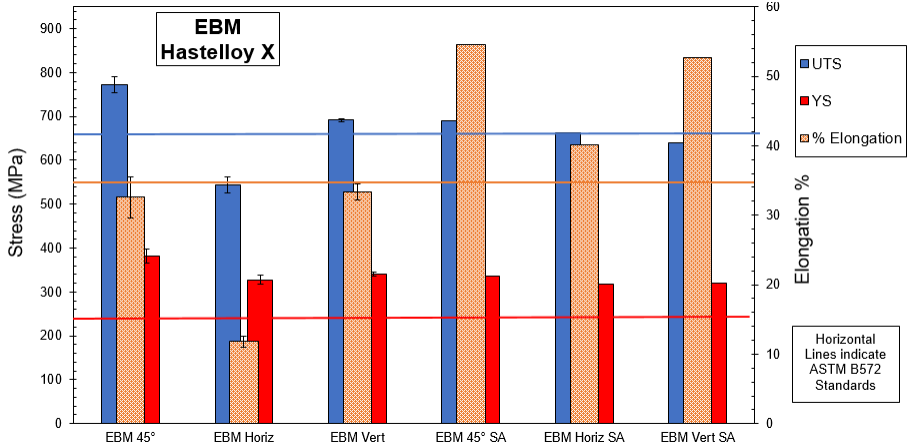
Accomplishments:

- 70+ Builds over 7 months
- Parameter Development
  - Arcam Algorithm Defects
  - Visual Defects
  - Surface Finish
  - Porosity and Microstructure

	May 2019		Dec. 2019
Surface Finish		→	

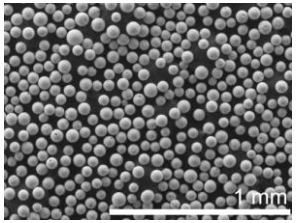
Tensile Tests:

- As-built Configuration
  - YS exceeds ASTM standards
  - UTS exceeds ASTM standards
    - » In 2 of 3 configurations
- After Post-Processing Heat Treat
  - YS exceeds ASTM standards
  - UTS exceeds ASTM standards
    - » In 2 of 3 configurations
  - % Elongation exceeds ASTM standards

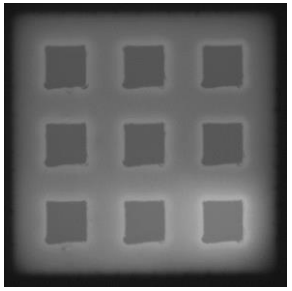


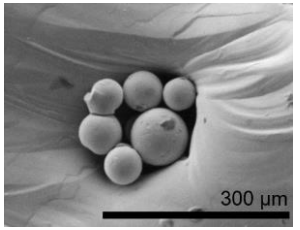
Molybdenum Build Overview

- Phase 1 Development
  - Mini-vat builds of pure Moly on the Arcam S12
  - Moly alloy melt tests on the Arcam S12
- Phase 2 Development
  - Large builds of pure Moly on the Arcam Spectra H
  - Mini-vat builds of Moly alloys on the Arcam S12 or other
- Phase 3 Development
  - Large builds of Moly alloys on the Arcam Spectra H

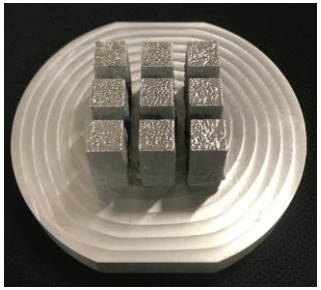


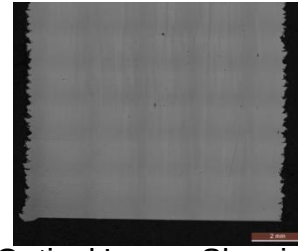
Virgin Moly Powder


NIR Image from Moly build 7 showing few defects



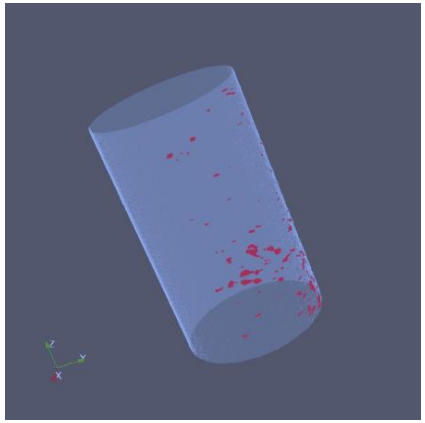
LOF Defect on surface of Mo Build 4


Moly Build 4

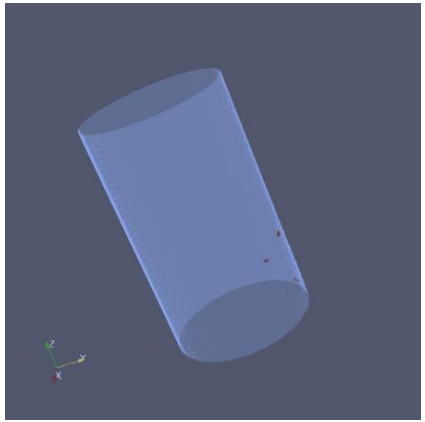

Optical Image Showing Crack Free Walls

Data Science Development and Digital Twins

- Machine learning algorithms for prediction of build effects and property prediction
- Develop accurate 3D *digital twin*
- GD&T
  - +/- 90um on edges
  - +/- 180 um edge to edge
- Pore Detection
  - 100um or larger at 99.99% detection
  - ~15% false positives
- Working method for in-situ crack detection



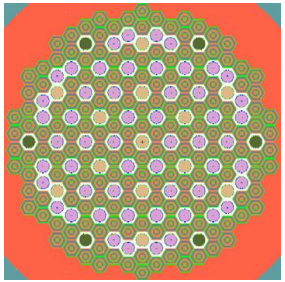
Significant porosity detected during fabrication of this solid structure (top)



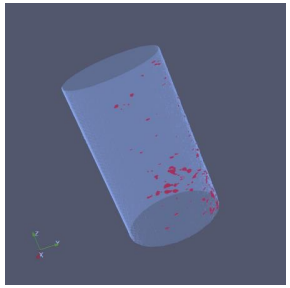
Verification of improvement (below)

Summary

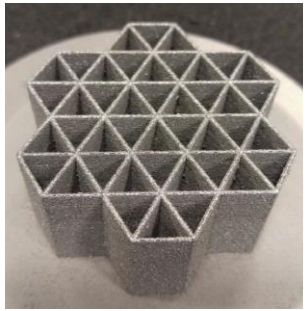
- Design
  - Completed multiple design/analysis iterations
  - Continue developing the VHTR and UHTR concepts
- Hastelloy® X Builds
  - Builds complete
  - Excellent mechanical properties
  - Acceptable as-built surface finishes
  - Acceptable GD&T
- Molybdenum Builds
  - Successful crack free bulk builds
  - Moly alloy melt test reveal crack free melt pools
- Data Science
  - Accurately develop 3D digital twin of as-built part
  - 99.99% pore detection
  - Successfully providing feedback loop to build strategy
  - Working on feedback loop to design/analysis software



Core Arrangement



3D Digital Twin



Molybdenum Test Build

HAST X Thin Wall Test Build