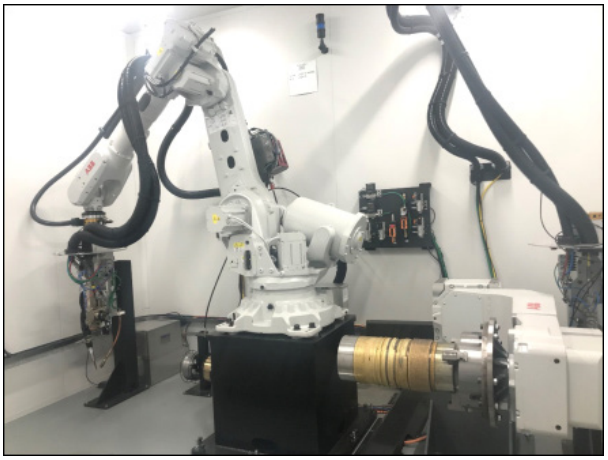
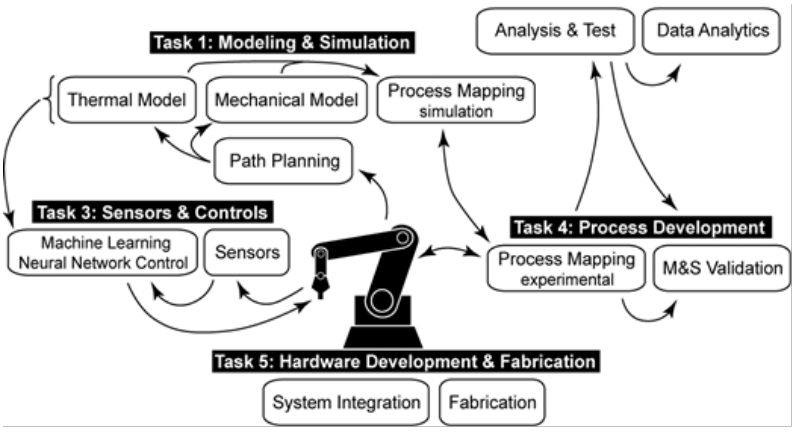
PROJECT SUMMARY 1113

# ONR Quality Made – Robotic Laser Wire Additive Manufacturing System with Comprehensive Quality Assurance Framework






*Wolf Robotics Laser Wire AM System that resides in the Manufacturing Demonstration Facility at Oak Ridge National Labs (left). Schematic showing the elements and interfaces of the framework being developed (right).*

## PROBLEM

The Navy plans to use additive manufacturing (AM) to supply out-of-production and long lead-time metallic components. Solutions need to ensure the manufacturability of metallic parts from a variety of AM machines and geographic locations. Certification costs of metal AM parts are a barrier to more extensive use. Advances in fundamental understanding and control of AM fabrication benefit the Naval supply chain by reducing the cost and time to modify, develop, and certify new/replacement parts. Recent advances in modeling and simulation tools based on an Integrated Computational Materials Engineering (ICME) approach provide an opportunity to relate process parameters to microstructure to properties to performance. Advanced sensor technology, distributed systems, and machine learning for use in process monitoring and control systems ensure the quality of AM fabricated parts.

## OBJECTIVE

The program objective is to define a framework that couples modeling tools, in-situ process measurements, real-time closed-loop control, and machine learning to meet performance requirements for AM parts. Predictive modeling tools are being implemented for the specific AM process variables and resulting microstructure predictions. Additional models for predicting mechanical properties based on microstructure characteristics are being verified with metallurgical testing and evaluations of Ti-6Al-4V AM specimens. Sensors are to be selected and tested for in-situ process monitoring with the goal of implementing these in-situ data into a closed-loop control system. The end goal is a framework that can provide real-time monitoring of the build, identify material variability and potential anomalies, and capture a build process history.

**AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP**

This project aligns to:

PROCESS

**ASTM PROCESS CATEGORY:** Directed Energy Deposition

**EQUIPMENT:** Custom Built Multi-Axis Equipment

**MATERIAL:** Ti-6Al-4V

## TECHNICAL APPROACH

This project engages explicit expertise from multiple sources. Lockheed Martin is the prime contractor responsible for integrating the entire system. Iowa State University is providing the model to predict microstructure. Carnegie Mellon is expanding the model to predict the mechanical properties from the microstructure. Colorado School of Mines is responsible for the metallurgical analysis, data analytics, model integration, and the sensor definition. GKN is developing the process map definition for the specific AM implementation and the design of experiments for test specimens, as well as supporting the AM specimen builds. Wolf Robotics is providing the AM system resident at the Manufacturing Demonstration Facility at Oak Ridge National Laboratories. America Makes is providing the project data management and dissemination. Each of the teammates has a breadth of knowledge of AM and brings a specific expertise to the project.

## PROJECT START DATE

July 2018

## EXPECTED END DATE

April 2020

## EXPECTED DELIVERABLES

- Final report
- Material and processing digital data package
- Interface control document
- Project review materials
- AM system and sensor and controls system specifications & calibrations
- Site plan & training document
- ICME modeling
- Verification and validation plan document
- List of property acquired/provided

## FUNDING

$5.8M total project budget

## PROJECT PARTICIPANTS

**Project Principal:**
Lockheed Martin

**Other Project Participants:**
Iowa State University
Carnegie Mellon University
Oak Ridge National Laboratory
GKN Hoeganaes
Wolf Robotics
Colorado School of Mines

**Public Participants:**
U.S. Department of Defense
National Science Foundation
U.S. Department of Energy



**NCDMM Headquarters**
486 Cornell Road
Blairsville, PA 15717
Phone: (724) 539-8811

**Letterkenny Offices**
4755 Innovation Way
Chambersburg, PA 17201
Phone: (717) 553-0068

**America Makes Offices**
236 West Boardman Street
Youngstown, OH 44503
Phone: (330) 622-4299

**ncdmm.org**

**AmericaMakes.us**