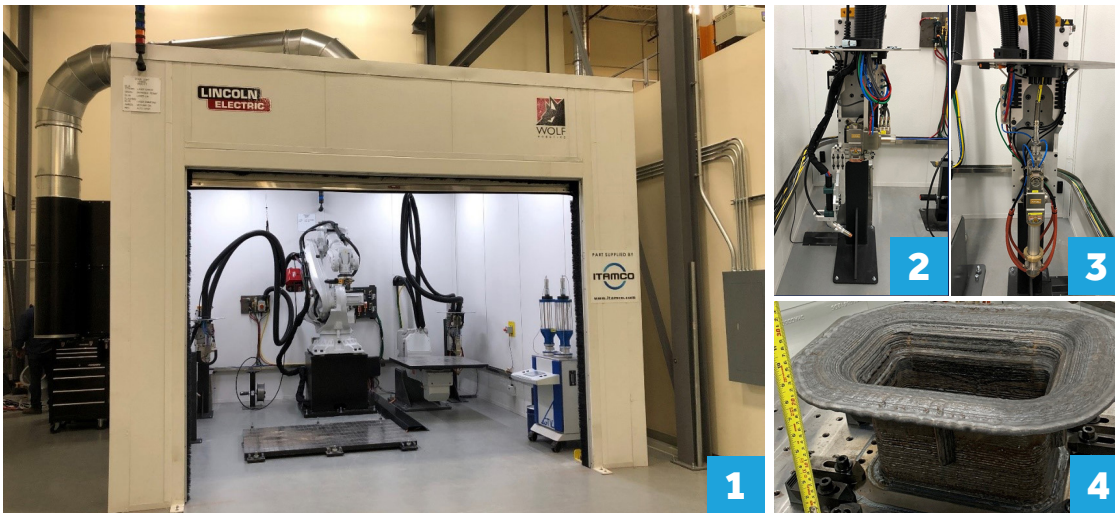


SUCCESS STORY

4062

*Develop a Prototype System for Future Commercialization of a Complete Multi-Axis System for Printing MAAM and BAAM Titanium, Steel, and Aluminum-Bronze Based Parts.*

## Increase AM Flexibility & Lower Costs Associated with Scalable Multi-Axis Robot Systems



1. Installed demonstrator system at Oak Ridge National Laboratories
2. Laser hot wire process head
3. Blown powder process head
4. UTRC demo part

### PROBLEM

There is no commercially available multiplanar CAD to path software tool to enable the manufacturing of Medium Area AM (MAAM) and Big Area AM (BAAM) parts through a single robot, cluster, or system of coordinated multi-axis robots using directed energy deposition (DED) methods with multi-meter, multi-process, multi-material capabilities.

Printing large complex parts with multi-meter build areas typically requires large, inflexible, expensive 3-axis gantry-based systems. These systems usually incorporate only one deposition modality through a single deposition head resulting in increased processing time as the part size increases. The high costs associated with such large, single head AM equipment drastically shrink the applicability of this technology on a wide array of industry applications.

### OBJECTIVE

The objective of this project was to develop technology (hardware and software) enabling the commercialization of a next generation DED metal AM machine. This technology promises to position the AM industrial user base to take full advantage of the lower cost and increased flexibility associated with scalable multi-axis robot systems. The project sought to build on existing alpha generation CAD to path AM robotic software tools by testing and refining the CAD to path tool for a future commercial first release. Basic process testing was planned to help develop a multi-process, multi-meter, multi-material prototype production robot-based 3DP system.



**AMERICA MAKES  
TECHNOLOGY  
DEVELOPMENT  
ROADMAP**

This project aligns to:



PROCESS

**ASTM  
PROCESS CATEGORY:**  
Directed Energy  
Deposition

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

**MATERIAL:**  
Titanium,  
Steel,  
AL-Bronze

## TECHNICAL APPROACH

The team approach was to construct a demonstration system to test and refine robotic 3DP hardware and software through the printing of team member challenge parts. This effort leveraged existing Wolf Robotics proprietary CAD to part printing tools to enable multi-axis (9 and above), multi-process (laser hot wire and blown powder) printing. Software features developed allowed a CAD model to be broken into sections that could be assigned to different processes, materials, and or robots within a robot cluster as part of a “build strategy” defined for a specific part by the software user. One robot was used for printing on this project; however, the project team investigated multi-robot coordination strategies to serve as a foundation for potential future projects related to multi-robot printing that addresses robot reach and collision avoidance.

## ACCOMPLISHMENTS

This project successfully leveraged expertise to design and manufacture a next generation multi-energy source (laser/hotwire), multi-feedstock, multi-meter scale robotic DED demonstration system. The system was able to successfully print two of the challenge parts to completion. Three materials (410 stainless steel, titanium, and aluminum-bronze) were successfully printed using the hot wire process. It was determined to be more economical to print bulk, coarse features at a significantly higher deposition rate than fine features.

Demonstrated successes through this program contributed to the formation of a new additive manufacturing business unit within Lincoln Electric (titled “Lincoln Electric – Additive Solutions”), parent company of Wolf Robotics, to print medium and large scale metal parts as a service to the industrial supply base. Plans for this new AM service bureau include more than twenty robotic-based DED systems printing complex large-scale metal parts and tools for a wide range of industries. Lincoln attributes early involvement in the America Makes program as influential in its decision to start this business unit.

## PROJECT START/END DATE

January 2017 - January 2019

## DELIVERABLES

- Multi-metal machine specification document
- Process monitoring methodology and tools report
- Demonstrator CAD model component design
- Print demonstrations
- Multi-robot coordinated printing literature review and assessment report
- Methodology to achieve tunable build resolution
- Process procedures and parameter sets
- Materials and part test results
- Workforce development course material

## FUNDING

### \$2.2M total project budget

(\$1.2M public funding/\$1M private funding)

## PROJECT PARTICIPANTS

### Project Principal:

Wolf Robotics

### Other Project Participants:

EWI

Oak Ridge National Laboratory

Lincoln Electric

University of Tennessee, Knoxville

IPG Photonics

Caterpillar

Case Western Reserve University

ITAMCO

GKN Aerospace

United Technologies Corporation

Youngstown Business Incubator

### Public Participants:

U.S. Department of Defense

National Science Foundation

U.S. Department of Energy

4062 Multi: Source/Feedstock/Meter-Scale Metal AM Machine

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