



# Additive Manufacturing Casting Replacement Optimization (AMCRO) – Heat Treating and Chemistry

<b>Task 1: Computational Modeling MIL-100S-1</b>		
 <b>QUESTEK</b> ★	 <b>PennState Applied Research Laboratory</b>	 <b>LINCOLN ELECTRIC</b>
Computational modeling (effect of alloying elements, predicted CCT diagrams, phase transitions, phase diagrams)	Literature review, prior experience, providing targeted heating and cooling conditions of interest	Providing previous experience with the feedstock alloys and CCT data (if available).
<b>Task 2: Modeling Wire Arc DED / Heat Treating</b>		
 <b>PennState Applied Research Laboratory</b> ★	 <b>JOHN DEERE</b>	 <b>LINCOLN ELECTRIC</b>
Finite element modeling of wire arc DED and heat treating processes (distortion, residual stresses, thick/thin HT profiles)	Prior heat treating experience, components and sizes of interest	Prior wire arc DED experience, components and sizes of interest
<b>Task 3: Wire Arc DED and Heat Treating of MIL-100S-1 Test Articles</b>		
 <b>PennState Applied Research Laboratory</b> ★	 <b>LINCOLN ELECTRIC</b>	 <b>JOHN DEERE</b>
Wire arc DED processing, in-situ process monitoring, data collection, small scale heat treating	Feedstock material, wire arc DED processing, guidance on processing parameters, small scale heat treating	Heat treating following design of experiments, guidance on heat treating parameters
<b>Task 4: Testing and Experimental</b>		
 <b>JOHN DEERE</b> ★	 <b>PennState Applied Research Laboratory</b>	 <b>LINCOLN ELECTRIC</b>
Mechanical testing (tensile strength, Charpy impact, dynamic tear), machining and extracting test samples	Material characterization, fracture surface analysis, chemistry testing, residual stress and distortion analysis	Jominy quench testing of selected alloys

*Pictorial representation of the project's technical plan including descriptions of project responsibilities for each organization*

## PROBLEM

Commercially available feedstocks that are often used for wire-arc directed energy deposition (DED) were not designed to serve as bulk material and therefore may not perform similarly to the original, cast materials. Although post-build heat treating is desirable to promote homogeneity, reduce residual stress, and perhaps enable relaxation of the interpass temperature constraints that are typically required for welding, there are no standardized heat treatment procedures for commercially available wire-arc feedstocks.

## OBJECTIVE

The objective of this effort is to develop and demonstrate an optimized wire-arc DED process and post-process heat-treating procedures for the casting replacement of HY-80 steel castings. This will be achieved by compiling available program data, determining and reviewing process/property relationships, and completing elemental refinement modeling with respect to MIL-100S-1.



**AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP**

This project aligns to:



**ASTM PROCESS CATEGORY**  
Directed Energy Deposition

**EQUIPMENT**  
Wire-Arc DED

**MATERIAL**  
HY-80, MIL-100S-1



### TECHNICAL APPROACH

This effort is being led by the Pennsylvania State University Applied Research Laboratory (PSU ARL). The first task will be to perform computational modeling of the MIL-100S-1 alloy to identify equilibrium, non-equilibrium phases, and phase transformation temperatures to help inform the optimum wire-arc DED processing conditions and post heat-treating conditions. This task will also investigate optimum chemistries within the MIL-100S-1 specification to help reduce the quenching sensitivity to allow for more uniform properties between thick and thin sections. The second task will involve thermo-mechanical modeling of the wire-arc DED process to better understand the optimum build path to assure in-process heating is maintained at acceptable levels to minimize distortion. This will also model the heat-treating response to understand expected heating and quenching curves as a function of distance from the surface. With the information gained from tasks 1 and 2, task 3 will produce builds by wire-arc DED and the builds will be sectioned for heat treating evaluations. Finally, task 4 will conduct material characterization on samples to assess the impact of various wire-arc DED processing and heat-treating conditions used.

### PROJECT START DATE

April 2023

### EXPECTED END DATE

January 2024

### EXPECTED DELIVERABLES

- Comprehensive final report containing, at a minimum, critical process parameters, lessons learned, standards used, and any deviations from those standards.

### FUNDING

#### \$493,829 total project budget

(\$293,786 in public funding/\$200,043 in private funding)

### PROJECT PARTICIPANTS

#### Project Principal:

Pennsylvania State University Applied Research Laboratory (PSU ARL)

#### Other Project Participants:

Questek  
John Deere  
Lincoln Electric

#### Public Participants:

U.S. Department of Defense