

AMNOW Challenge for Analysis of Digital Thread Additive Manufacturing and Post-Processing Data – Phase 1

1.0 Introduction

As Metal Additive Manufacturing is advancing from primarily a prototyping process to being used in serial production, the process and material data generated are critical to parts qualification. The National Center for Defense Manufacturing and Machining (NCDMM) through their AMNOW Program seeks to leverage artificial intelligence and data analytics to a significant data set of Additive Manufacturing (AM) digital thread data to discover trends and insights into the repeatability and predictability of the Laser Powder Bed Fusion (LPBF) process. These data sets encompass over thirty-six (36) 316L powder AM builds of parts and eight hundred (800) coupons, collected across three (3) machine models, six (6) machines, three (3) facilities, and two (2) heat treatments and other post processes.

2.0 Scope/Project Objectives

The purpose of the AMNOW Metals Challenge is to leverage analytics to correlate material and process input data to material property data. The dataset was collected through three NCDMM Project Agreements and contains the following build layouts and data from the Fuel Elbow parts:

- Build layout in STEP or STL format
 - Build 1: Elbows and Coupons using a layout developed by Penn State ARL
 - Builds 2,3,7-12: Representative Production Builds of Elbows and Coupons
 - Builds 4-6: Simulated Machine Operational Qualification – Coupons Only
- In-situ AM machine data (.amrp) in JSON format from the following equipment, Concept Laser M2, EOS M290, and Renishaw AM400 (limited data)
- Post-Processing data in the following formats and per the following templates:

Type	Format	Template	Notes
Powder Certs	Excel	AMNOW-913	
Thermal Processing	Excel	AMNOW-978	
Radiographic Inspection	Excel - Guide	AMNOW-979	Links Radiographs to Part
	Radiographs	DICONDE	
Coupon Testing	Excel	AMNOW-990	May Not Have Build 1 Results
Microstructure	JPG / PNG	none	

3.0 Background

NCDMM issued Project Agreements to Penn United Technologies, ATI Specialty Metals and Innovative 3D Manufacturing for the following:

- a) Be the recipient of technical information transfer from Penn State ARL, including a build layout of Fuel Elbows and coupons already approved by NCDMM to demonstrate production confidence building.
- b) Reproduce the initial Fuel Elbow build (aka Build #1) provided by Penn State ARL and process completely according to the manufacturing sequence defined in TDP 1091635_01.

- c) Produce two additional builds (aka Builds #2 & #3) that include a majority of Fuel Elbows to increase production quantities, with only typical lot acceptance coupons.
- d) Prepare a final operational qualification (OQ) PCD that complies with AMS 7003 and AMNOW 977 for material between 1mm and 12mm thick.
- e) Produce three identical builds (aka Builds #4 - #6) of coupons to serve the purpose of a simulated OQ, as described in AMS 7032. These builds will also be used to develop specification minimums for AMS-7036.
- f) Produce six (6) additional builds (aka Builds #7 - #12) that include a majority of Fuel Elbows to increase production quantities, with only typical lot acceptance coupons.

4.0 Applicable Documents and Data Provided

The following documents contain requirements and practices to be followed in executing this ASOW. In case of conflict, the order of precedence is: 1) Project Agreement 2) This ASOW, 3) Documents referenced in this ASOW, 4) Referenced ATDP, 5) Documents referenced in the applicable ATDP. Underlined documents will be provided by NDCMM, with most provided digitally or hardcopy after contract award.

<u>Document #</u>	<u>Document Name</u>	<u>Version</u>
<u>TDP 1091635_01</u>	Fuel Elbow TDP	A
AMS 7003	Laser Powder Bed Fusion Process	Current
<u>AMS 7032</u>	Machine Qualification for Fusion Metal Additive Manufacturing	Draft
<u>AMS 7036</u>	Laser Powder Bed Fusion produced parts, steel, corrosion and heat resistance, 17Cr – 13Ni – 2.5Mo (316L), Hot Isostatic Press	Draft
<u>AMS 7039</u>	Laser Powder Bed Fusion produced parts, steel, corrosion and heat resistance, 17Cr – 13Ni – 2.5Mo (316L), Stress Relief and Anneal	Draft
<u>AMS 7037</u>	Steel, Corrosion and Heat-Resistant, Powder for Additive Manufacturing, 17Cr – 13Ni – 2.5Mo (316L)	A
ASTM-E1742	Standard Practice for Radiographic Inspection	-18
<u>AMNOW-931</u>	Supplier Data Specification – Laser Powder Bed Fusion	Current
<u>AMNOW-978</u>	Supplier Data Specification – Thermal Processing	Current
<u>AMNOW-979</u>	Supplier Data Specification – Radiographic Testing	Current
<u>AMNOW-913</u>	Supplier Data Specification – Feedstock Certification	Current
<u>ALC Test Data, Photo, Micrograph labeling</u>	A Lab Corp Instruction Sheet Sample	Sample

5.0 Requirements

The Project Agreement Holder (PAH) is responsible for execution of all of the following activities, including acquisition of any equipment or software and management of their personnel and subcontractors.

5.1 Data Download and Kick Off meeting

- 5.1.1** PAH shall gain access to the AMNOW Metals Challenge SharePoint and download applicable AMNOW documents and build and post processing data, referenced in Section 2.0. Note: PAH will be required to execute AMNOW certification of destruction/deletion of data upon project completion.
- 5.1.2** Attend a web Kick Off meeting to introduce PAH and NCDMM personnel, discuss project outcomes and address any issues or questions.

5.2 Conduct Interviews with AM suppliers

Attend a series of web meetings with the AM builders and NCDMM personnel to provide insight into their build process, machine properties, etc. Questions shall be submitted to amnow@ncdmm.org for approval at least 2 days prior to conducting interviews.

5.3 Analyze and Correlate Data

- 5.3.1** Utilize software models proposed and approved during selection process to link and correlate the data associated with the build and post-processing data files.

5.4 Identify Trends, Anomalies, and Insights

- 5.4.1** Compare associated data to identify trends, anomalies, and insights into the builds.
- 5.4.2** Identify potential flaws that could indicate an AM build quality issue.

5.5 Predict

- 5.5.1** Create algorithms to predict key results (such as coupon post process test results) and apply these algorithms to multiple builds.

5.6 Identify Opportunities for Improvement

- 5.6.1** Develop recommendations for final builds 13-14 to improve quality and material property results.

5.7 Report Findings

- 5.7.1** Findings will be compiled in a 5-page summary report to include recommendations for the final two builds. Summary report may be published on the America Makes Digital Storefront or equivalent.
- 5.7.2** Compile and present summary of findings (not to exceed 30 minutes including reserved time for questions) to Evaluation Board for potential Project Phase 2 participation.
- 5.7.3** Compile and present summary of findings (15-30 minutes) suitable for presentation during an America Makes event. Presentation must be submitted to NCDMM to obtain US Army approval for release. This may also be published on the America Makes Digital Storefront or equivalent.

6.0 Coordination Meetings

PAH shall participate in the following coordination meetings, at a mutually convenient time:

- 6.1.1** (5.1.2) Kick-off – 1 hr Web meeting
- 6.1.2** (5.2) Multi-party Q&A with Penn United – 1 hr Web meeting
- 6.1.3** (5.2) Multi-party Q&A with ATI – 1 hr Web meeting
- 6.1.4** (5.2) Multi-party Q&A with Innovative 3D Manufacturing – 1 hr Web meeting
- 6.1.5** (5.7.2) PAH Final Presentation of findings to Evaluation Board – 30 Min Web meeting
- 6.1.6** (5.7.3) PAH Final Presentation of findings at America Makes Event – 15-30 Min Web or in-person meeting

Deliverables

Line Item	SOW Reference	Title of Deliverable	Data Rights
1	5.1.2	Kickoff Meeting	Limited
2	5.7.1	Submit summary report	Unlimited
3	5.7.2	Presentation of Findings to Evaluation Board	Unlimited
4	5.7.3	Presentation of Findings at America Makes Event	Unlimited

7.0 Version History

Version	Description of Change	Approval	Date
A	Initial Release	A.Totin	7 FEB 2022