

ASOW 156 - AMNOW Challenge for Analyzing AM Digital Thread Data with Intentional Anomalies in Material Extrusion – VER A- 2022-04-13

1.0 Introduction

Material Extrusion is the most accessible form of 3D Printing (also known as Additive Manufacturing) because of the affordability of machines and materials. While high-cost industrial machines and feedstock are making aerospace-grade parts, achieving the same degree of consistency and quality has been beyond the capability of low-cost desktop printers. In-situ monitoring using low-cost sensors and data analysis offers the potential to evaluate the quality of a part without expensive or destructive testing. Ultimately, when this monitoring is coupled with closed-loop feedback, the ability to produce industrial-grade components with lower-cost printers and feedstocks could be realized.

The National Center for Defense Manufacturing and Machining (NCDMM) through their AMNOW Program seeks to apply artificial intelligence and data analytics to a data set of Additive Manufacturing (AM) Material Extrusion digital thread data to discover anomalies and trends in Material Extruded parts. These data sets encompass over 30 parts made from PETG with the Material Extrusion process, and associated pressure analysis, collected across two (2) Prusa i3 MK3 machines.

2.0 Scope/Project Objectives

The purpose of the **AMNOW Challenge for Analyzing AM Digital Thread Data with Intentional Anomalies in Material Extrusion (AMNOW Polymer Challenge)** is:

- To determine the feasibility of using artificial intelligence algorithms to find anomalies in in-situ data sets and correlate them with actual part quality
- To stimulate development and discussion of artificial intelligence algorithms for finding anomalies in in-situ data sets within the material extrusion 3D printing community
- To create motivation for industry machine providers to incorporate data collection and monitoring features in their products

The challenge datasets were collected under the AMNOW program from a series of campaigns at Colorado State University and contain machine, equipment, and external sensor data that can be used to identify anomalies intentionally introduced into certain builds. The data will be released in two phases:

The first phase will contain manufacturing data from two sets of builds, the first of which will contain known good parts or “control builds” and the second which will contain a mixture of good parts and parts with intentional anomalies introduced. The objective is to identify the “anomalous parts” by analyzing the provided manufacturing data sets.

The second phase contains additional post-build test data relating to the introduced anomaly. The objective of phase 2 is to determine the severity of the anomalies on a scale of 0-100 (slight to catastrophic failure).

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Phase 1 Data

During the first phase of the challenge, participants will have access to the following data:

- Build layout in STL format
- Slicer and version used
- Printer used and firmware version
- Filament type, manufacturer, and filament spool data
- In-situ AM machine data (.amrp) in JSON format
- Final .gcode used for part printing
- Additional sensor data in .csv format, providing such data as current, bed level, filament diameter, motor current, ambient temperature and humidity, slicer settings and more.

Sensor	Phenomena Observed
Inline Filament Diameter	Filament diameter, filament diameter variation, filament runout
Bed Level (PINDA-Prusa)	Bed distance, bed flatness tolerance, average surface normal unit vector
Main Current (full printer)	Brown-outs, variations in printer current draw
Current at motors and heaters	Heating cartridge current, bed heating element current, individual motor current
Slicer settings	All settings, such as brim, skirt, infill, speeds, flow, etc.
Ambient Temperature and Humidity Sensor	Ambient temperature, relative humidity
Printer Controller (LIMS)	Nozzle position, TMC drivers error reporting, E position, hotbed and bed temperature

Phase 2 Data

During phase 2 of the challenge, participants will be provided with additional test data including:

Data	Type
Pressure test	Time vs Pressure

Under this ASOW, the entities are expected to:

- a) Be the recipient of process definition and process data from NCDMM
- b) Identify anomalies and spot trends
- c) Develop a method of analysis for material extrusion manufacturing data that could predict anomalies
- d) Phase 1: Deliver up to 5-page summary report and 30-minute presentation with key findings of part quality, data trends and analysis, and recommendations for data or build process improvements.
- e) Phase 2: Revisit Phase 1 findings and use Phase 2 data to glean additional insights into anomalies and their severity. Deliver this in a up to 5-page summary report and 30-minute presentation

3.0 Applicable Documents Provided

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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.

<u>Document #</u>	<u>Document Name</u>	<u>Version</u>
N/a	Overpressure Relief Dome (STL File)	Current

4.0 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.

4.1 Data Download and Kick Off meeting

4.1.1 PAH shall gain access to the AMNOW Polymer Challenge SharePoint and download applicable AMNOW documents and build and test data, referenced in Section 2.0. Note: PAH will be required to execute AMNOW certification of destruction/deletion of data upon project completion.

4.1.2 Attend a web Kick-Off meeting to introduce PAH and NCDMM personnel, discuss project outcomes and address any issues or questions.

4.2 Conduct Interviews with Colorado State University

Attend a web meeting with the part builder Colorado State University and AMNOW program 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.

4.3 Produce a Data Processing Method to Analyze and Correlate Data

4.3.1 Utilize software models proposed and approved during selection process to link and correlate the data associated with the build and test data files.

4.3.2 Determine which parts contain possible anomalies along with their location in the in the part using the provided data.

4.3.3 Determine the type of possible anomalies in the part using the provided data (e.g., over-extrusion).

4.4 Discover the Anomaly(s) that were introduced

4.4.1 Compare associated data to identify trends, anomalies, and insights into the builds.

4.4.2 Identify potential flaws that could indicate an AM build quality issue.

4.4.3 Identify anomalous builds in the data set

4.4.4 Stretch goal: Identify the location of the leak(s) in the anomalous parts

4.5 Predict

4.5.1 Create algorithms to predict key results (such as pressure for a failure) and apply these algorithms to multiple builds.

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4.6 Report Findings and Part Quality

- 4.6.1** Findings will be compiled in a 5-page summary report to include the findings from 4.3 – 4.5. The summary report may be published on the America Makes Digital Storefront or equivalent.
- 4.6.2** Compile and present summary of findings (not to exceed 30 minutes including reserved time for questions) to Evaluation Board.

4.7 Receive Phase 2 Data & Predict

- 4.7.1** Using pressure test and leak results, verify findings and predictions from Phase 1.
- 4.7.2** Determine the magnitude of the problem – how far is the variance from “normal”
- 4.7.3** Determine the severity of any possible anomalies on a scale of 0-100 using the provided data (0 being a catastrophic failure, 100 indicating a perfect process).
- 4.7.4** Produce a go/no-go criteria that filters anomalous part from good parts

4.8 Report Findings and Part Quality

- 4.8.1** Updated findings will be compiled in a 5-page summary report. Summary report may be published on the America Makes Digital Storefront or equivalent.
- 4.8.2** Compile and present summary of findings (not to exceed 30 minutes including reserved time for questions) to Evaluation Board.
- 4.8.3** 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.

5.0 Coordination Meetings

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

- 5.1.1** (4.1.2) Kick-off – 1 hr Web meeting
- 5.1.2** (4.2) Q&A with Colorado State University – 1 hr Web meeting
- 5.1.3** (4.6.2) PAH Preliminary Presentation of Phase 1 findings to Evaluation Board – 30 Min Web meeting
- 5.1.4** (4.8.2) PAH Final Presentation of Phase 2 findings to Evaluation Board – 30 Min Web meeting
- 5.1.5** (4.8.3) PAH Final Presentation of findings at America Makes Event – 15-30 Min Web or in-person meeting

6.0 Deliverables

Line Item	SOW Reference	Title of Deliverable	Data Rights
1	4.1.2	Kickoff Meeting	Limited
2	4.6.1	Submit Preliminary Summary Report of Phase 1 Findings	Unlimited
3	4.6.2	Presentation of Phase 1 Findings to Evaluation Board	Unlimited
4	4.8.1	Submit Final Summary Report Including Phase 2 Findings	Unlimited
5	4.8.2	Presentation of Phase 2 Findings to Evaluation Board	Unlimited
6	4.8.3	Presentation of Final Findings at America Makes Event	Unlimited

7.0 Version History

Version	Description of Change	Approval	Date
A	Initial Release	A.TOTIN	4/6/2022