

# Supporting Army readiness through a robust digital additive manufacturing supply chain



## Project Call Industry Brief

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**Problem:** Desktop 3D Printers are widely available and affordable, but rarely used to make anything beyond prototypes and toys. Using in-situ monitoring and low-cost sensors, is it possible to have confidence in the quality of material extrusion polymer parts made on desktop printers?

**Opportunity:** The AMNOW program produced over 30 parts made from PETG on Material Extrusion Desktop 3D Printers equipped with in-situ monitoring and low-cost sensors. Anomalies were intentionally introduced into some of the parts. The AMNOW program is now seeking those with experience in data analysis to review the data and identify anomalous parts.

## AMNOW Challenge Objectives:

- 1) Determine the feasibility of using AI to find anomalies in in-situ data sets and correlate them with actual part quality
- 2) Stimulate development and discussion of artificial intelligence algorithms for finding anomalies in in-situ data sets within the material extrusion 3D printing community
- 3) Create motivation for industry machine providers to incorporate data collection and monitoring features in their products

## Overview:

- Phase 1: Given manufacturing data, identify which of the parts in the test set are anomalous
- Phase 2: Given test data, identify the leak location

## Contract:

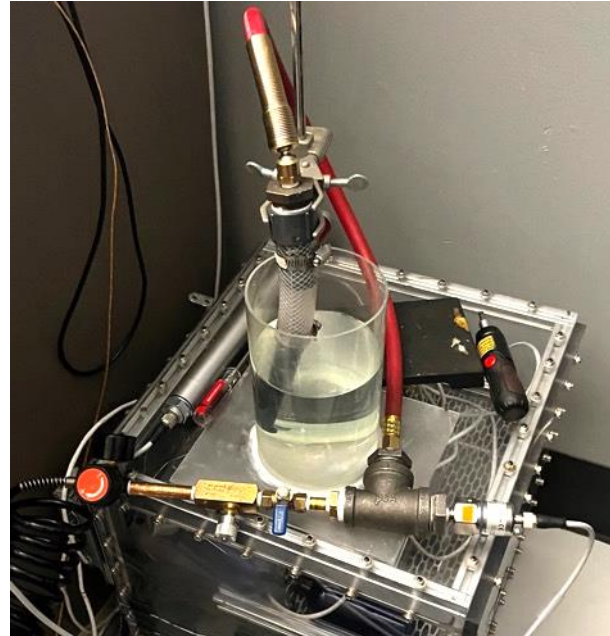
- Up to \$20k Award

## Over 5 Total Builds

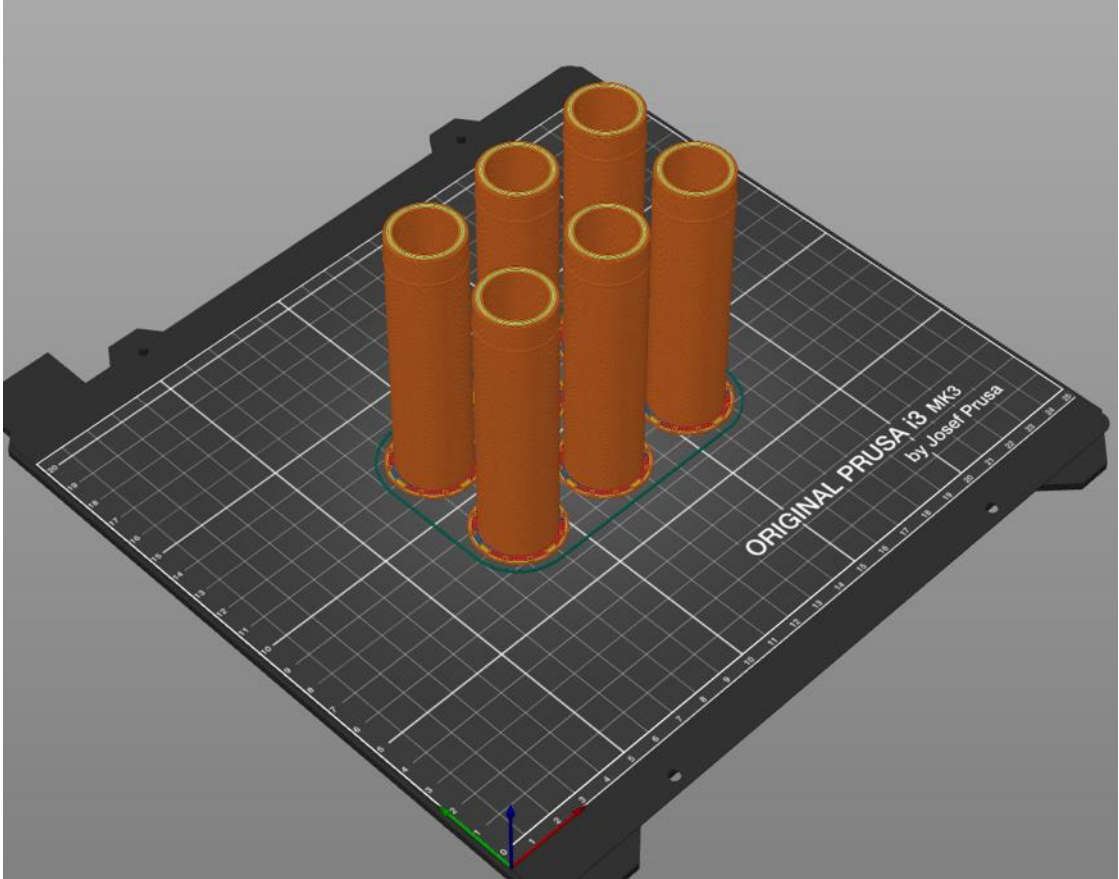
- Control parts
- Additional builds, which have intentional anomalies introduced.

## Testing

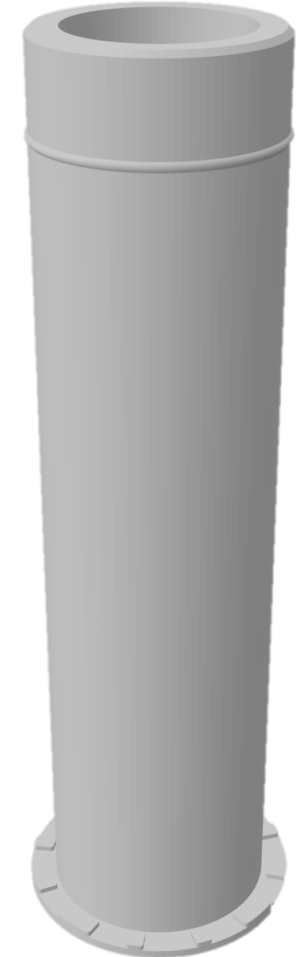
- Each part is pressure tested by filling the part with compressed air at 1 psi, sealing it off, and allowing the pressure to slowly decay over time. The pressure decay of the part is recorded.



## Build layout



- Build Layout – STEP or STL
- Print – LIMS JSON – Next Slide
- Pressure Test Data
- Sensor Data per Table

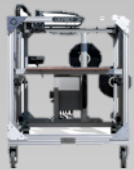


Sensor	Phenomena Observed
Inline Filament Diameter	Filament diameter, filament diameter variation, filament runout
Bed Level (PINDA-Prusa)	Bed distance, bed flatness tolerance, average surface normal unit vector
Main Current (full printer)	Brown-outs, variations in printer current draw
Current at motors 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

# Time Series Data for Material Extrusion Origins



## Controller



Make	Infill Pattern
Model	Job KWH
Serial #	Layer Height
Calibration Date	Line Width
Control Software Rev	Nozzle Diameter
Axis Positions (XYZ)	Extruder-1 Temp
Layer	Extruder-1 Target
Build Plat Pos	Print Speed
Build Plat Speed	Shop Humidity
Build Plate Temp	Shop Temperature
Build Plate Target	Utilization
Extruder Temp	Wall Thickness
Extruder Target	Dryer Temp
Filament Lot #	Dryer Target
Infill Density	Filament Diameter
Infill Overlap	

## Environment

Current



Shop Temperature

Shop Humidity



## LIMS - Analytics

Layer Height

Job KWH

Shop Temp

Shop Humidity

Part Start Time

Part End Time

Part Time

Part Counter

Avg KWH

Utilization

Running

Efficiency

Avg Efficiency



## Header Information

ASOW153-LPBF - 12/3/2021 2:51:46 PM

Amip Version - 1.22

### Operations Reports

- AMNOW Document # - 931
- AMNOW Part # - 9
- Build # - 7
- Build ASOW - 153
- Build ID - 12/436
- Device ID - LIMS-DEVICE-3
- Edge Device Version - 4.0.22027.0
- End Time-2021-12-06 02:33:25 AM
- Group # - APDP-2
- Job Uuid - 00000000-0000-0000-0000-000000000000
- Latitude - 40.86063
- Longitude - -74.45232
- Part Builder Name - Penn United Technologies
- Part Builder Short Name - PUT
- Part Name - ASOW153-LPBF
- Part Uuid - 00000000-0000-0000-0000-000000000000
- Start Time-2021-12-03 02:51:46 PM

## 65 KPIs

### Step1:Printing

- Address -
- BuildBoxSerialNumber -
- BuildPlatformPosition - (MILLIMETER) --- [4208 Items]
- BuildPlatformSpeed - (MILLIMETER/SECOND) --- [1278 Items]
- BuildPlatformTemp - (CELSIUS) --- [18030 Items]
- CalibrationDate -
- ChamberAbsoluteHumidity - (PERCENT)
- ChamberO2Con - 0.0 (PERCENT)
- ChamberO2ConBottom - (PERCENT)
- ChamberO2ConTop - (PERCENT) --- [20518 Items]
- ChamberTemperature - (CELSIUS)
- CollectorPlatformPosition - (MILLIMETER)
- CollectorPlatformSpeed - (MILLIMETER/SECOND)
- CollimatorTemperature - (CELSIUS)
- ControlSoftwareRev -
- DispenserFillLevel - (PERCENT)
- DispenserPosition - (MILLIMETER)
- DispenserSpeed - (MILLIMETER/SECOND)
- DosageFactor - (PERCENT)
- EndTime - 2021-12-06 02:33:25 AM
- EnvironmentHumidity - (PERCENT)
- EnvironmentTemp - (CELSIUS) --- [15858 Items]
- FilterO2Con - (PERCENT)
- FilterPressure - 0.0 (PSI)
- FiltrationConfig -
- FiltrationHistory -
- GasFlowConfig -
- GasFlowHistory -
- InertGasFlowRate - Ar (LITER/MINUTE)
- InertGasType - Ar
- InfillDensity - (PERCENT)
- InfillOverlapPercent - (PERCENT)
- InfillPattern -
- JobKWH - 0 (WATT\_HOURS)
- LaserPower - (WATT)
- LaserTemp - (CELSIUS)
- Layer - --- [1683 Items]
- LayerThickness - (MICROMETER)
- MachineClass -
- Make -
- Material - --- [2 Items]
- Model -
- Notes -
- OpticalTrainConfig -
- OpticalTrainHistory -
- ParameterDataSet -
- PartFile -
- ProcessGasFlowBottom - (LITER/MINUTE)
- ProcessGasFlowTop - (LITER/MINUTE)
- ProcessMonitor -
- RecoaterAxisTorque - (NEWTON-METER) --- [65234 Items]
- RecoaterMechConfig -
- RecoaterMechHistory -
- RecoaterPosition - (MILLIMETER) --- [5048 Items]
- RecoaterSpeed - (MILLIMETER/SECOND) --- [4102 Items]
- ScanHeadTemperature - (CELSIUS)
- SerialNumber -
- ShopHumidity - (PERCENT) --- [845 Items]
- ShopTemperature - (CELSIUS) --- [15858 Items]
- StartTime - 2021-12-03 02:51:46 PM
- Tip -
- TurbineAxisTorque - (NEWTON-METER)
- TurbinePosition - (MILLIMETER)
- TurbineSpeed - (MILLIMETER/SECOND)
- Utilization - (PERCENT) --- [170937 Items]

## Single Report File

- JSON Format
- Data Array contains simple arrays
- Includes Type and Units



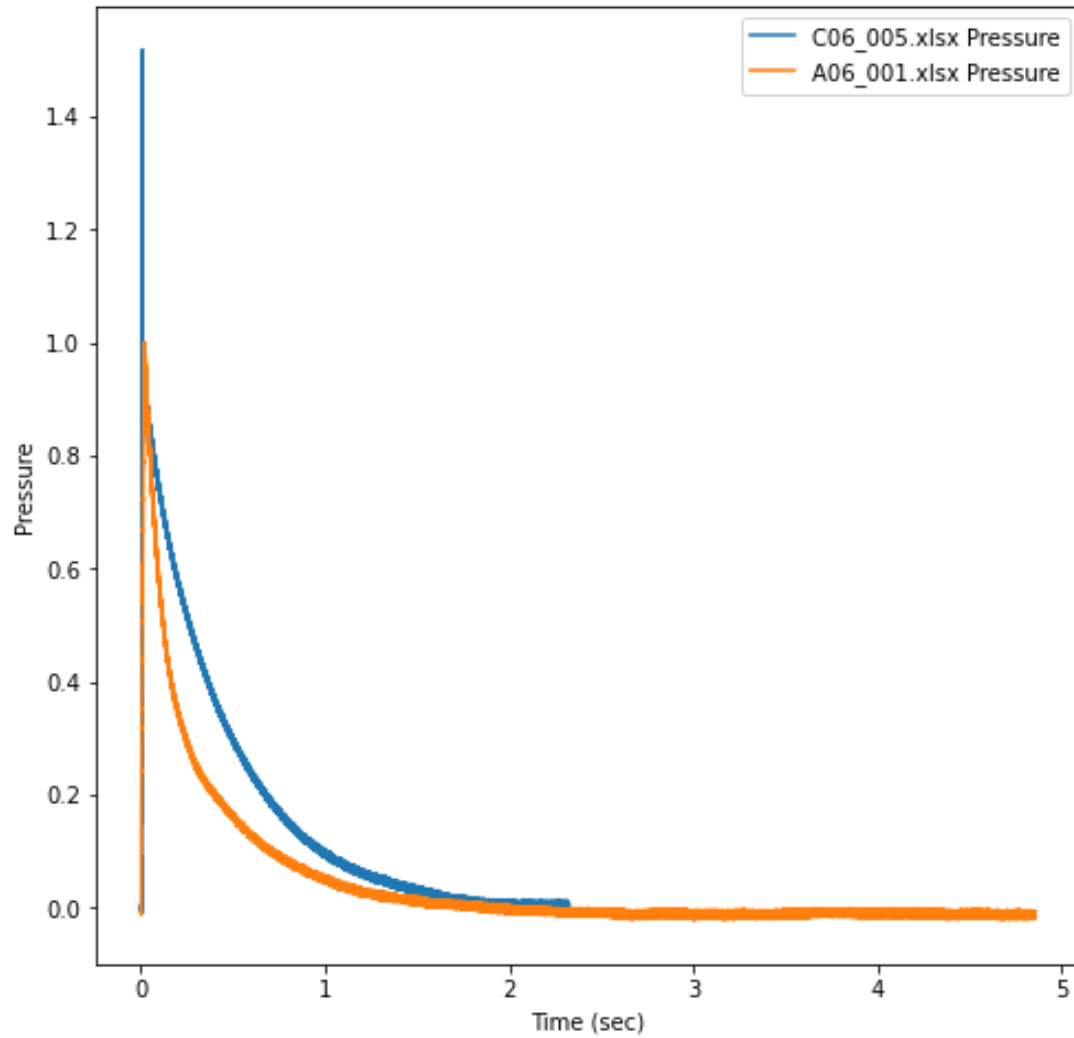
## JSON

```
{
  "Name": "LayerHeight",
  "EquipmentType": "JobHistory",
  "ID": null,
  "Value": "",
  "Units": "MILLIMETER",
  "Scale": 0.0,
  "Offset": 0.0,
  "DataType": "double",
  "Action": "",
  "SeriesData": [
    {
      "ValueTime": "2022-01-29 08:51:26 PM",
      "Value": "0"
    },
    {
      "ValueTime": "2022-01-29 08:54:23 PM",
      "Value": "0.05"
    },
    {
      "ValueTime": "2022-01-29 08:55:09 PM",
      "Value": "0.2"
    },
    {
      "ValueTime": "2022-01-29 09:01:06 PM",
      "Value": "0.1999999999999999"
    },
    {
      "ValueTime": "2022-01-29 09:01:16 PM",
      "Value": "0.2"
    }
  ]
}
```

## Solution Builder®

BuildPlatformTemp - (CELSIUS) --- [18030 Items]
2021-12-03 02:51:46 PM - 149.899993896484
2021-12-03 02:51:52 PM - 149.966995239258
2021-12-03 02:52:05 PM - 149.932998657227
2021-12-03 02:52:15 PM - 149.966995239258
2021-12-03 02:52:25 PM - 149.899993896484
2021-12-03 02:53:05 PM - 149.867004394531
2021-12-03 02:53:15 PM - 149.932998657227
2021-12-03 02:53:25 PM - 149.899993896484
2021-12-03 02:54:05 PM - 149.932998657227
2021-12-03 02:54:15 PM - 149.899993896484
2021-12-03 02:54:25 PM - 149.966995239258
2021-12-03 02:54:35 PM - 149.932998657227
2021-12-03 02:54:45 PM - 149.966995239258
2021-12-03 02:54:55 PM - 149.899993896484
2021-12-03 02:55:05 PM - 150
2021-12-03 02:55:15 PM - 149.932998657227
2021-12-03 02:55:25 PM - 149.966995239258
2021-12-03 02:55:35 PM - 150
2021-12-03 02:55:45 PM - 149.932998657227
2021-12-03 02:55:55 PM - 150
2021-12-03 02:56:05 PM - 149.932998657227





- Phase 2 data will include pressure vs time data.
- All test parts exhibited some leak over time.
- Pressure decay recorded; example shown.

## Build 1

- Time Series Data (LIMS JSON)
- Sensor Data
- Pressure Series Data (Released in Phase 2)

## Build 2

- Time Series Data (LIMS JSON)
- Sensor Data
- Pressure Series Data (Released in Phase 2)

## Build X....

- Time Series Data (LIMS JSON)
- Sensor Data
- Pressure Series Data (Released in Phase 2)

## Key Dates

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RFP Released	April 6, 2022
Project Call Webinar	April 12, 2022
Project Call Announcement and Posting	April 13, 2022
Questions from Proposers Due	April 22, 2022
Responses to Proposers	April 25, 2022
Full Project Proposal Submission Due	April 29, 2022
Phase 1 & 2 Awardees Notified	May 3, 2022
Project Agreement Issued	May 13, 2022
Phase 1 Oral Team Presentations to Evaluation Team	June 24, 2022
Phase 2 Oral Team Presentations to Evaluation Team	July 25, 2022
Presentation of Findings at America Makes Event	Week of August 15, 2022

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## Technical – Contained in 15min Presentation for the Evaluation Board

- Addressing ASOW-156
- Draft Execution Plan and Schedule
- List of approach and proposed software or tools, including description of off-the-shelf or proprietary tools.  
**\*\*Will be disqualified if this is not included.**
- What they plan to demonstrate
- Experience they have working with material extrusion, artificial intelligence, and data analytics

## Programmatic

- Participating Organizations
- Identification of Single Person from Team to Access SharePoint and Download Data
- Willingness to present results at an America Makes or NCDMM Sponsored event in 2022
- Additional administrative information per RFP

**Registrants to the Industry Brief will Receive Email with Link to RFP**

# Selection Criteria to Enter Phase 1



## Contained in 15min Presentation for the Evaluation Board Address in the Following in Proposal Response

- Approach for Addressing ASOW-156 Including: – 40%
  - Correlation of Machine and Sensor Data
  - Identification of Process Anomalies
  - Correlation of Phase 1 and Phase 2 Data
  - Identification of Anomaly Location
- Draft Execution Plan and Schedule - 5%
- Proposed software or tools, including description of off-the-shelf or proprietary tools\*\*
  - Uniqueness – 15%
  - Description Details – 15%
  - Computing Efficiency – 15%
- Experience they have working with material extrusion, artificial intelligence, and data analytics – 10%

- RFP Website:  
[https://www.americamakes.us/project\\_calls/amnow-polymer-challenge-april-2022/](https://www.americamakes.us/project_calls/amnow-polymer-challenge-april-2022/)
- Register as a Supplier on the AMNOW AMIP Platform: <https://www.myamnow.com>