TRACE AM

ADDITIVE MANUFACTURING

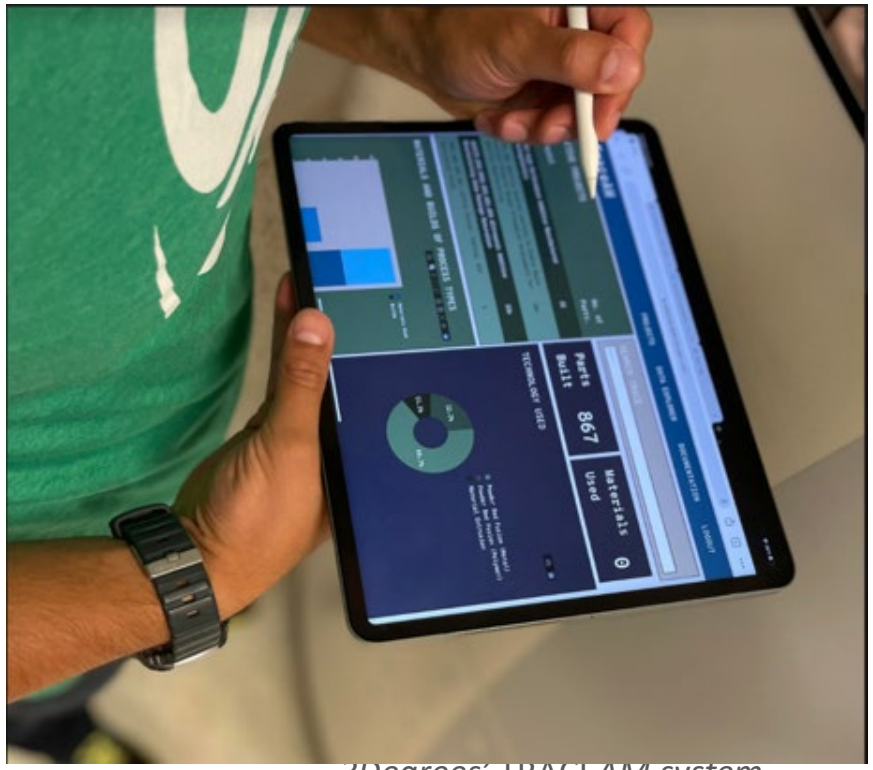
DATA ORGANIZATION AND ANALYSIS

What is TRACE*AM?*

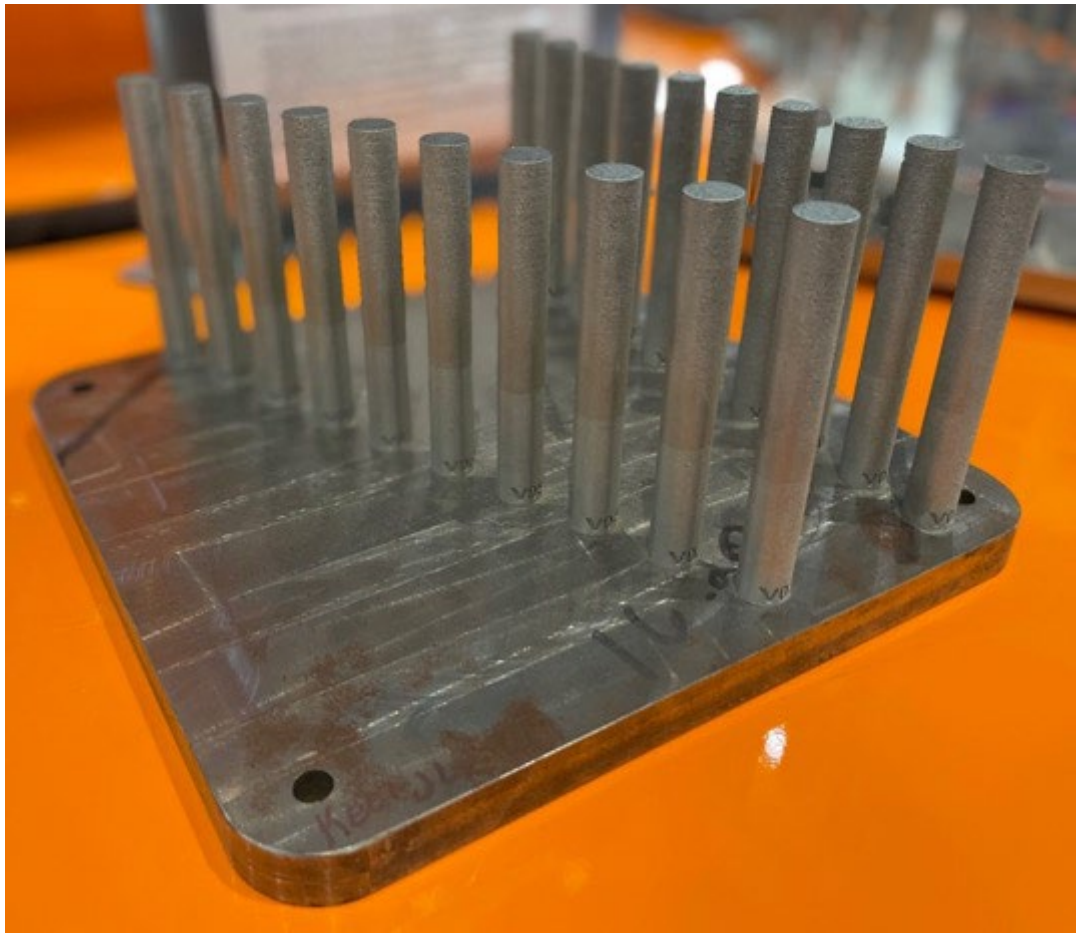
3Degrees' TRACE*AM* software is a streamlined platform designed to effectively organize, analyze, and deploy critical technical data packages related to Additive Manufactured parts. It is a secure and customizable interface ideal for use in development and sustainment operations, enabling rapid and qualified part solutions across DoD and its supply base. Engaged with several commercial customers and have been part of five funded America Makes projects.

Current Challenges

- 3D Printing materials qualification is **SLOW (>18 months) and EXPENSIVE ($1.5 million) per part per material per parameter set.**
- 3D Printing technical data has become unmanageable due to the quantity, speed, and variety of information coming through the AM workflow.
- Research, production improvements and technology adoption are limited by disparate data sources, little coordination, no reproducibility
- Centralizing the collection and storage of this data improves data reliability and frees up engineers time for higher impact activities



*3Degrees' TRACE*AM system*



Industry Listening Tour

- We've completed over 100 customer discovery interviews of potential commercial users. 96% of these organizations had no formal structure for managing their AM data.
- Rather, they used basic spreadsheet tools (Excel) and had no centralized strategy for leveraging this information.
- This was true not only for small companies (1-2 production printers) but also the case for large organizations (3+ printers) that had already invested over a million dollars into hardware
- Estimated $1-1.5 million dollars and 18 months to qualify a single material on a single machine

Initial Case Study

Problem Statement:

Currently, when users log into the America Makes Digital Storefront they see a text-heavy dashboard listing historical projects, with project data is stored in a variety of formats (e.g., Word, Excel, PDF). Although this is perfectly suitable for accessing certain types of data (e.g., project final reports, TRX PPT presentations), it makes it difficult for a member to see comparative data or trend analysis.

Objectives:

We proposed to build a functional database utilizing 3Degrees' TRACE*AM* software, which is specifically designed to collate 3D Printing data according to the workflows of the 3D Printing process

Team:

AIR FORCE RESEARCH LABORATORY
SENVOL
3DEGREES
Deloitte.
NORTHROP GRUMMAN
EOS

Industry efforts to build AM data sets are already underway

- NASA is working with various industry and academic partners (led by Auburn University) to help in the development of an initial database of key properties from a number of alloys to help accelerate feasibility properties (not A-basis) and modeling efforts through the NASA RAMPT program

- Several AM alloys of interest have been characterized by various commercial companies, however a majority of the data is proprietary and not accessible

- Best practices applied from NASA MSFC-SPEC-3717 (along with MSFC-STD-3716)
  - Characterization and evolution of the materials during heat treatments
  - Recommending heat treatment schedules
  - Complete basic mechanical and thermophysical property testing
  - Tensile from -320F through 1800F +
  - Low Cycle Fatigue at various strains from -320F through 1600F
  - High cycle fatigue testing as allows at various strains
  - Thermal conductivity, CTE

AM Alloys and Processes In-work

Material	Process
Haynes 282	L-PBF
Haynes 282	LP-DED
Hastelloy X	L-PBF
Hastelloy X	LP-DED
Inconel 625	L-PBF
Inconel 625	LP-DED
Inconel 625	LW-DED
Inconel 625	AW-DED
Inconel 718	L-PBF
Inconel 718	LP-DED
Inconel 718	AW-DED
Inconel 939	L-PBF
Haynes 230	L-PBF
Haynes 230	LP-DED
Haynes 214	L-PBF
Haynes 233	L-PBF
Haynes 233	LP-DED

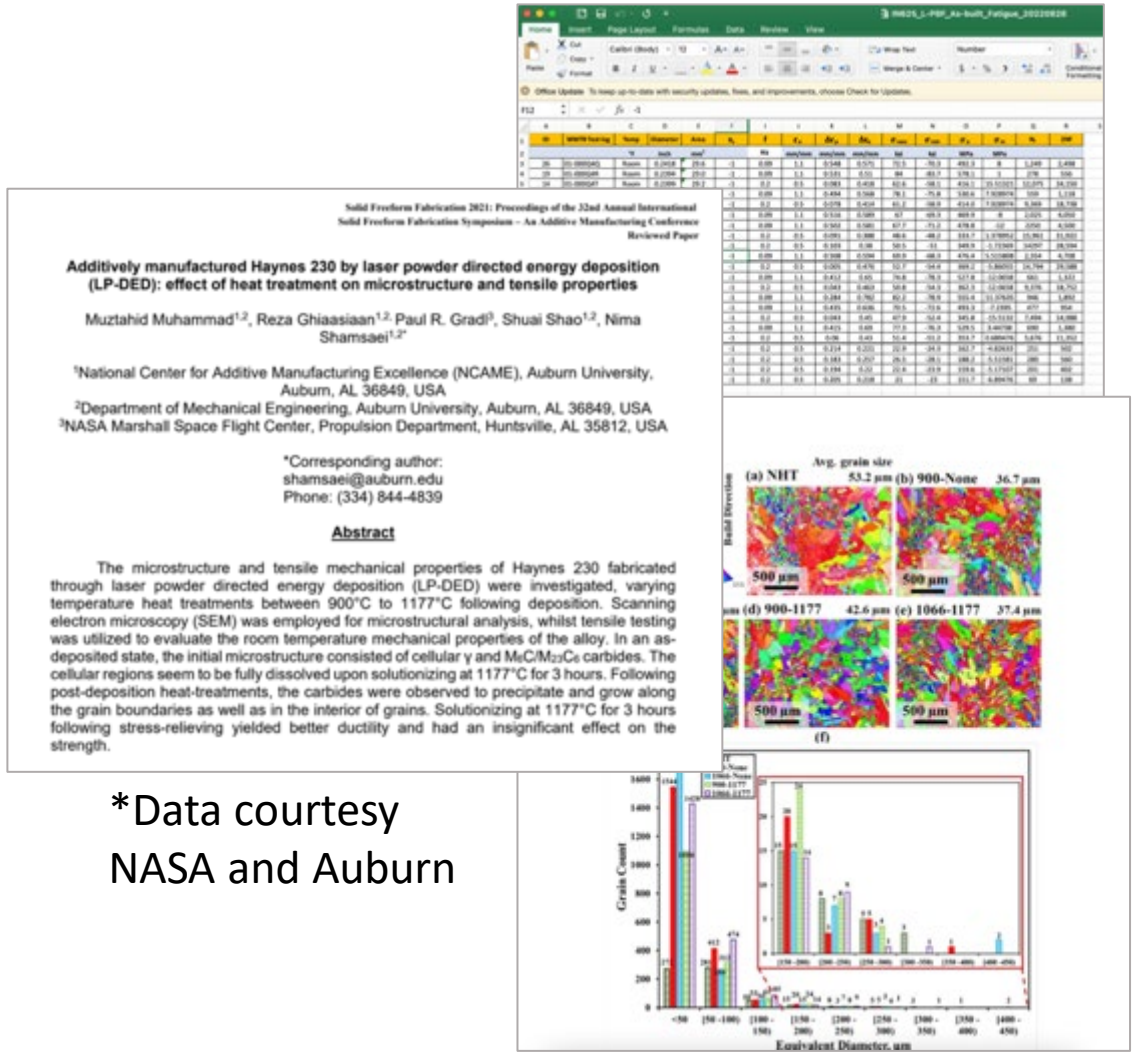
55+ Alloys in characterization

Material	Process
NASA HR-1	L-PBF
NASA HR-1	LP-DED
JBK-75	L-PBF
JBK-75	LP-DED
CoCr	L-PBF
CoCr	LP-DED
Invar 36	LP-DED
Stellite 21	LP-DED
316L	LP-DED
15-5	LP-DED
17-4	L-PBF
17-4	LP-DED
Scalmalloy	L-PBF
6061-RAM2	L-PBF
6061-RAM2	LP-DED
F357	L-PBF
F357	LP-DED
1000-RAM10	L-PBF
AlSi10Mg	L-PBF
AlSi10Mg	LP-DED
7A77	L-PBF

Material	Process
Monel K500	LP-DED
Monel K500	L-PBF
GRCop-42	L-PBF
GRCop-42	LP-DED
GRCop-84	L-PBF
C-18150	L-PBF
Ti6Al-4V	L-PBF
Ti6Al-4V	LP-DED
Ti6Al-4V	LW-DED
Ti6Al-4V	EBW-DED
Ti6242	L-PBF
Ti6242	LP-DED
GRX-810	L-PBF
GRX-810	LP-DED
Haynes 214-ODS	L-PBF
C-103	LP-DED

*Data courtesy NASA and Auburn

Currently developing lessons learned from digitally tagging and curating the NASA MSFC data using TRACEAM in collaboration with the CDME at the Ohio St University



Solid Freeform Fabrication 2021: Proceedings of the 32nd Annual International Solid Freeform Fabrication Symposium – An Additive Manufacturing Conference
Reviewed Paper

Additively manufactured Haynes 230 by laser powder directed energy deposition (LP-DED): effect of heat treatment on microstructure and tensile properties

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Abstract

The microstructure and tensile mechanical properties of Haynes 230 fabricated through laser powder directed energy deposition (LP-DED) were investigated, varying temperature heat treatments between 900°C to 1177°C following deposition. Scanning electron microscopy (SEM) was employed for microstructural analysis, whilst tensile testing was utilized to evaluate the room temperature mechanical properties of the alloy. In an as-deposited state, the initial microstructure consisted of cellular γ and $M_6C/M_{23}C_6$ carbides. The cellular regions seem to be fully dissolved upon solutionizing at 1177°C for 3 hours. Following post-deposition heat-treatments, the carbides were observed to precipitate and grow along the grain boundaries as well as in the interior of grains. Solutionizing at 1177°C for 3 hours following stress-relieving yielded better ductility and had an insignificant effect on the strength.

*Data courtesy
NASA and Auburn

CDME

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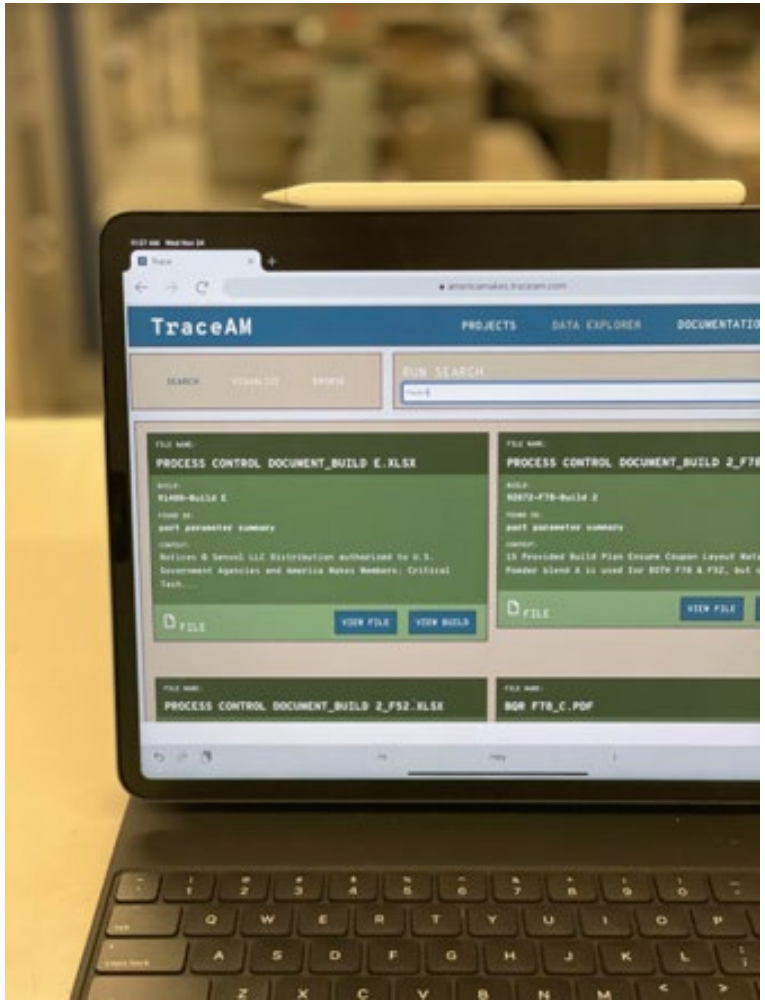
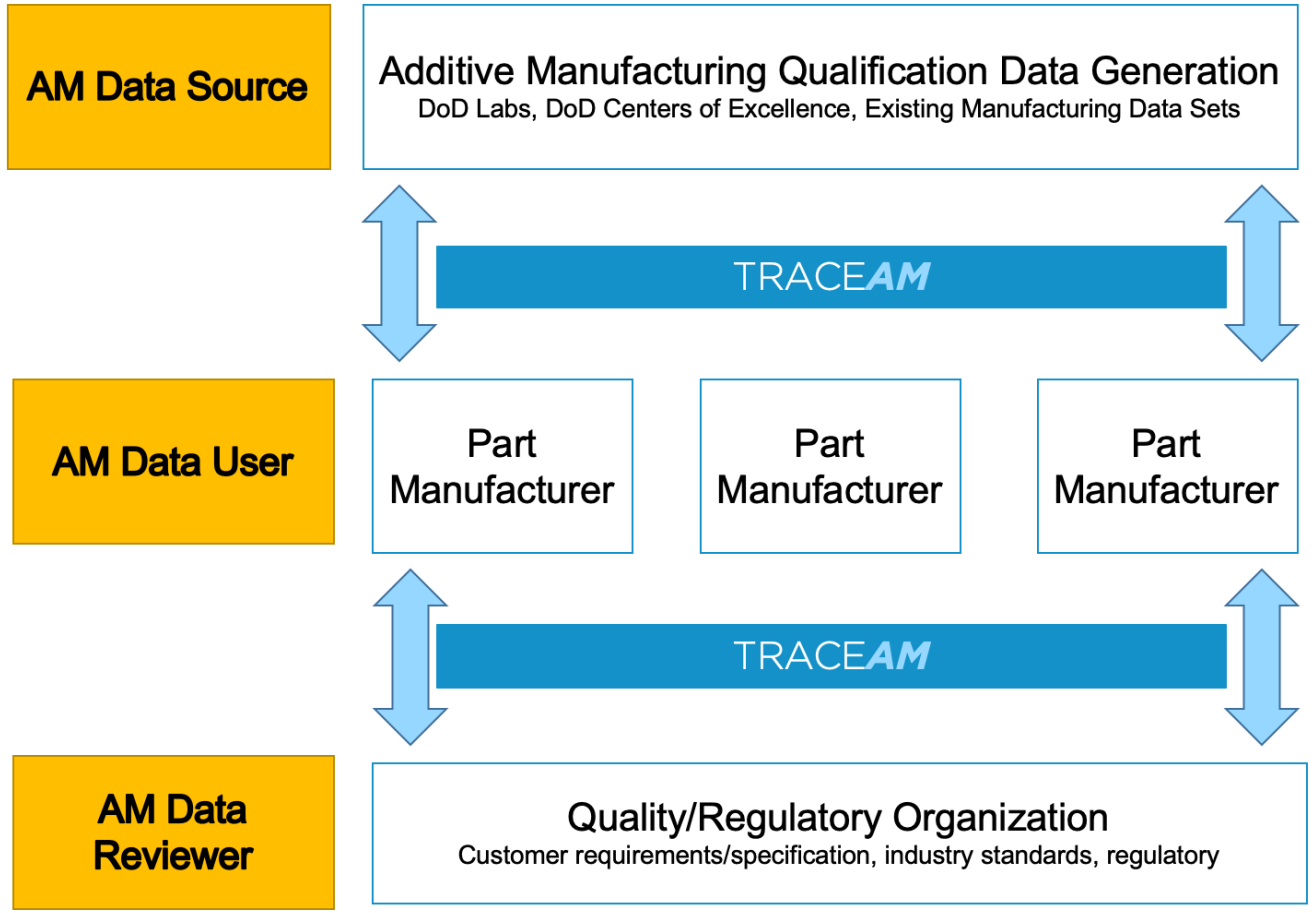


Enabling the DoD AM Supply Chain

Commercial Extension:
We are building on the work of our Phase II DoD SBIR by partnering with the DoD supply chain. Our aim is to create a path for federated, pedigreed, and validated AM digital data and workflows that can extend to DoD suppliers.



Discussions Points

1. What data are you wanting to manage (PDFs, text, numerical, graphs, etc.)?
2. How are teams interacting with the information (various stakeholders)?
3. How can we help people articulate a security strategy that makes sense?
4. What are the key insights that we want this data for? (ie Show me the last ten builds and the average elongation at break.)