Standards for AM Data and Data Packages

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National Institute of Standards and Technology
U.S. Department of Commerce

Overview

Data Packages for AM Parts - PWI 52923

Addresses the packaging of information and data requirements to communicate between designer, manufacturer, and inspection

In PWI (proposed work item) stage
Goal to go to ballot in 2021

Complements ISO TC 184 and STEP communities, complements MIL-STD-31000B

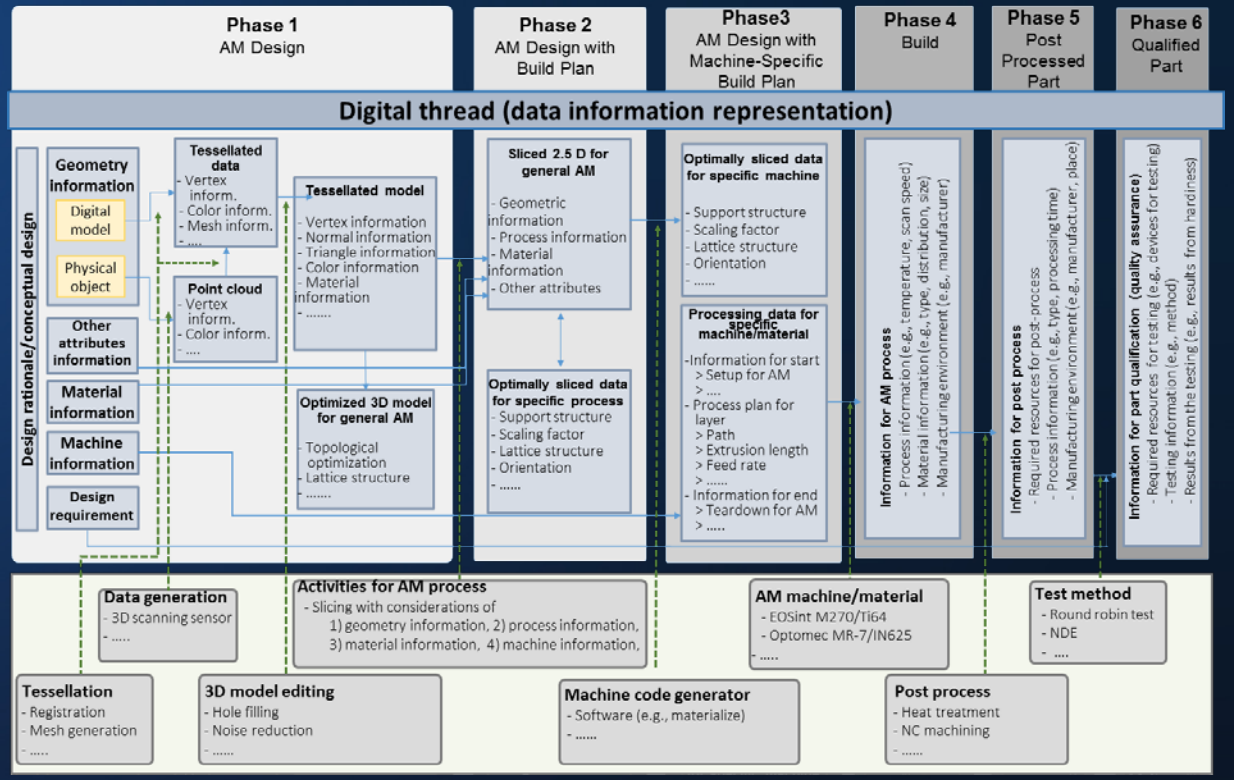
Overview of Data Pedigree- WK72172

Defines key terms for sharing detailed process and material information

In Pre-ballot state with initial feedback being incorporated

Aims to facilitate the sharing of AM data for materials development, learning, and qualification

Additive Manufacturing— Data Packages for AM Parts — PWI 52923



ISO/TC 261/JG 73 "Joint ISO/TC 261-ASTM F 42 Group; Digital product definition and data management"

Content Overview

Structured/Explicit Information Requirements

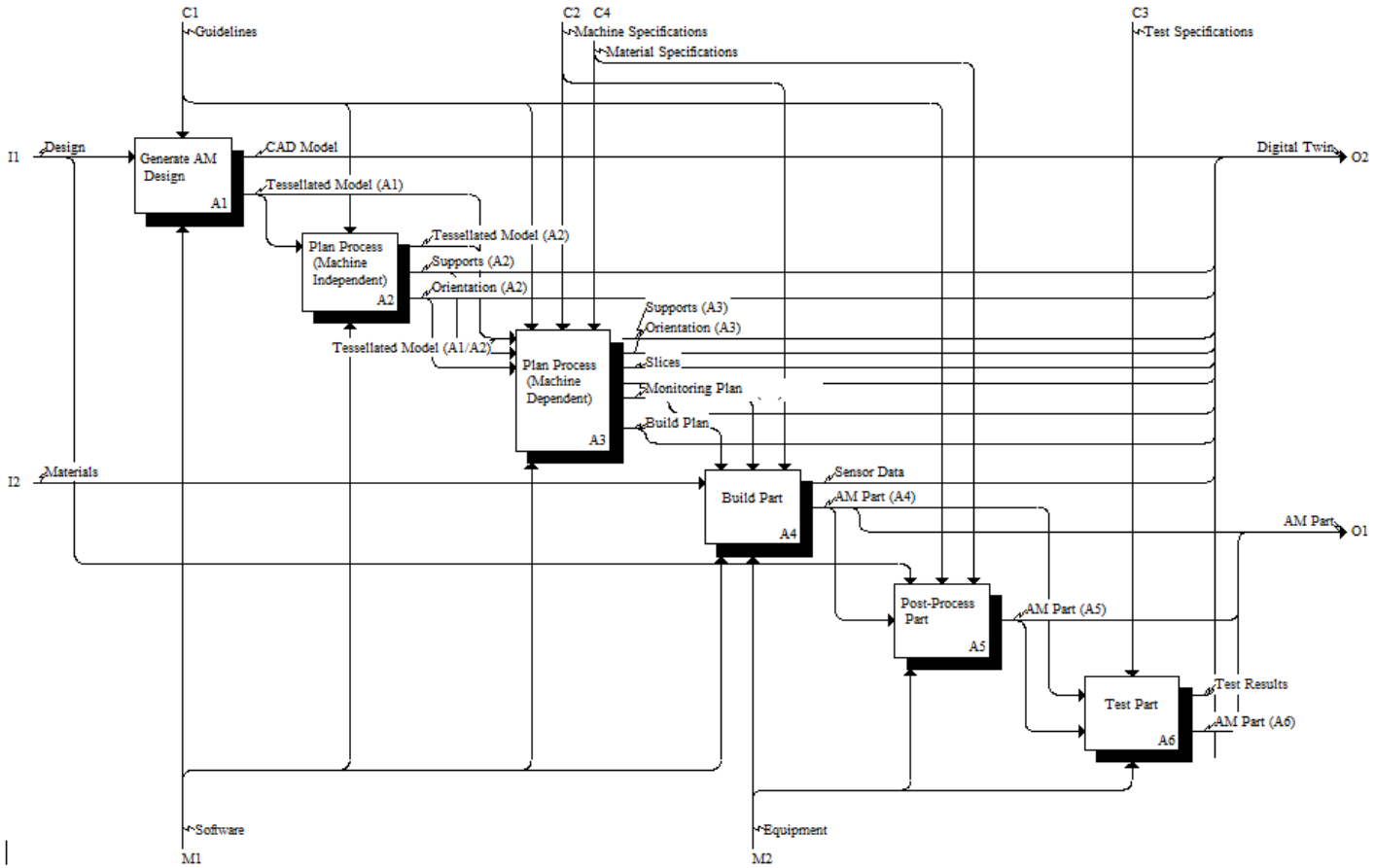


Figure 1. Decomposition of AM Workflow

	Sub-categories	Attributes	Low	Medium	High
A1	Design Plan	•Identification Data - NSN	×	×	×
		•3D model	×	×	×
		- Point clouds: point data set of XYZ coordinates	×	×	×
		- Finished Part Model	×	×	×
		- with surface treatments, including drill-on-assembly features			×
		-with fully dimensioned, toleranced & GD&T applied			
		-Blank Part Model, including designated surfaces for stock addition/ & possibly the stock-add amount			
		-Intermediate Part Model, including secondary machining processes & sequence on designated surfaces			
		• Material type (e.g., Ti6Al4V and IN625)			
		• Design requirements			
	3D tessellated model	• Plan for 3D model generation		×	×
		• XYZ Coordinates and its connectivity between nodes		×	×
		• Surface resolution of 3D model		×	×
		- Chordal distance		×	×
		• Facet type (e.g., triangular, rectangular)		×	×
	AM Design Specification	• Accuracy (resolution)		×	×
		• Feature manufacturability		×	×
		- Min/max manufacturable feature size		×	×
		- Thickness/under cut		×	×
		- Edge/gap/overhang length		×	×
		•Specification for surfaces receiving whole part treatments (e.g. anodizing, painting)			
		•Specification for limited area treatments (e.g. chrome plating)			
		•Primary [i.e. Blank], Intermediate and Final Part condition acceptance testing/ acceptance criteria -e.g. Full Clean-up, no undercut			
		•Callouts			
		-surfaces receiving limited area treatments (e.g. chrome p			
		-surfaces receiving whole part treatments (e.g. anodizing,			
		-post-build Thermal Treatment [i.e. Stress Relief]			
		-Final Property Heat Treatment			
		-Material Feedstock			
		-AM Machine/ AM Process to be used			
		-Interfaces with other part numbers -			
		-Overall manufacturing sequence -			

Configurable Data Packages

By Use Case

Acquisition | Manufacture in House | Verification Only

Part Maturity \ Process Maturity	Expeditionary	Developmental	Production
Prototype	General {G1, G2, G4.1} Part{P2, P3.1, P4.3} Material{M1} Inspection{I2.1}		
New Part			
Existing Part			

Configuration of Elements from:
G=General; M=Material; P= Part; I=Inspection

By Criticality/Capability

	High Capability	More Capability	Medium Capability	Less Capability	Low Capability
High Critical	Medium Control	Medium to High Control	High Control	Not Recommended	Not Recommended
More Critical	Medium to Low Control	Medium Control	Medium to High Control	High Control	Not Recommended
Medium	Low Control	Medium to Low Control	Medium Control	Medium to High Control	High Control
Less Critical	Low Control	Low Control	Medium to Low Control	Medium Control	Medium to High Control
Low Critical	Low Control	Low Control	Low Control	Medium to Low Control	Medium Control

Configured based on level of specificity required based on experience of stakeholder (designer, manufacturer, inspector)

Configuration of Data Packages

By Use Case

Acquisition

Part Maturity \ Process Maturity	Expeditionary	Developmental	Production
Prototype	G1; P1	M1; P1,2	
New Part	M1; P1	M12, P1	M1; P1,2; I1,2
Existing Part	M1; P2	M1,2; P1,2	M1; P1,2; I2

Configuration of Elements from:
G=General; M=Material; P= Part; I=Inspection

Different Scenarios:

- Use Case
  - Acquisition, Manufacture, Verification
- Part Maturity
  - Prototype, New Part, Existing Part
- Process Maturity
  - Expeditionary, Developmental, Production

Have Different Data Needs:

- Prototype
  - Expeditionary [P1]
  - Developmental [M1, P12]

Asserting Levels of Control

By Criticality/Capability

	High Capability	More Capability	Medium Capability	Less Capability	Low Capability
High Critical	Medium Control	Medium to High Control	High Control	Not Recommended	Not Recommended
More Critical	Medium to Low Control	Medium Control	Medium to High Control	High Control	Not Recommended
Medium	Low Control	Medium to Low Control	Medium Control	Medium to High Control	High Control
Less Critical	Low Control	Low Control	Medium to Low Control	Medium Control	Medium to High Control
Low Critical	Low Control	Low Control	Low Control	Medium to Low Control	Medium Control

Different organizations may require different levels of control

	Sub-categories	Attributes	Low	Medium	High
A1	Design Plan	•Identification Data - NSN	×	×	×
		•3D model	×	×	×
		- Point clouds: point data set of XYZ coordinates	×	×	×
		- Finished Part Model	×	×	×
		- with surface treatments, including drill-on-assembly features			×
		-with fully dimensioned, toleranced & GD&T applied			
		-Blank Part Model, including designated surfaces for stock addition/ & possibly the stock-add amount			
		-Intermediate Part Model, including secondary machining processes & sequence on designated surfaces			
		• Material type (e.g., Ti6Al4V and IN625)			
		• Design requirements			
	3D tessellated model	• Plan for 3D model generation		×	×
		• XYZ Coordinates and its connectivity between nodes		×	×
		• Surface resolution of 3D model		×	×
		- Chordal distance		×	×
		• Facet type (e.g., triangular, rectangular)		×	×
		• Accuracy (resolution)		×	×
		• Feature manufacturability		×	×
		- Min/max manufacturable feature size		×	×
		- Thickness/under cut		×	×
		- Edge/gap/overhang length		×	×
		•Specification for surfaces receiving whole part treatments (e.g. anodizing, painting)			
		•Specification for limited area treatments (e.g. chrome			

Security Considerations

- Part Security
  - Actions taken against counterfeiting
  - Actions taken to secure part
  - Actions taken to secure value chain/ traceability
- Cybersecurity
  - Encryptions used for digital datasets
  - Encryption used for data package
  - Requirements placed on supply chain

Concepts addressed in this document but further refined in an accompanying document.

In Development: Configuration Management

Design Model	
Description:	Native CAD file
Purpose:	Provide part geometry and material
Information:	Design, GD&T
Formats:	See Table A1

Transformation

Description:	Design to Print Model
Purpose:	Re-interpret design geometry to create a file type more suited for fabrication
Information Loss/Gain:	See Table B1

Print Model	
Description:	Pre-Process Geometry Model
Purpose:	Provide design information in a format easily prepared for layer by layer manufacture
Information:	Design, GD&T
Formats:	See Table A2

	STL	AMF	3MF	STEP	STEP-NC
Purpose	Printing	Printing, information model	Printing	Product model	Product model, manufacturing
Format, Schema		XML, XSD	XML, XSD	STEP Part 21, EXPRESS	STEP Part 21, EXPRESS
Tessellated Geometry	Unstructured triangles defined by vertices, normal vectors	Mesh defined by list of vertices and triangles indexed to the vertices, normal and edge vectors, curved triangles, recursive subdivision	Mesh defined by list of vertices and triangles indexed to the vertices	Mesh defined by list of vertices and triangles indexed to the vertices, normal vectors, groups of triangles, edges, multiple tessellations, association with exact geometry and tolerances	
Material		Composite materials, functional representation of heterogeneous materials	Composite, multi materials	Single material	Single material
Lattice Structures	Any geometry can be modeled	Functional representation of lattice geometry	Any geometry can be modeled	Any geometry can be modeled	Any geometry can be modeled
Build Orientation,		Orientation and placement of	Arrangement of objects in build		

- Process workflow to address
  - The exchange of information
  - Activities,
  - File formats
- Insight into capabilities of different file types
  - Address exchange of information
  - Address preservation of information
- Help with identification of ownership of information

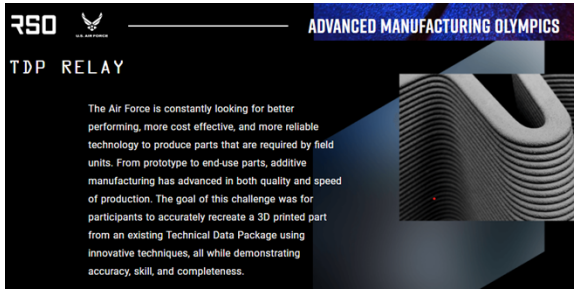
Current State

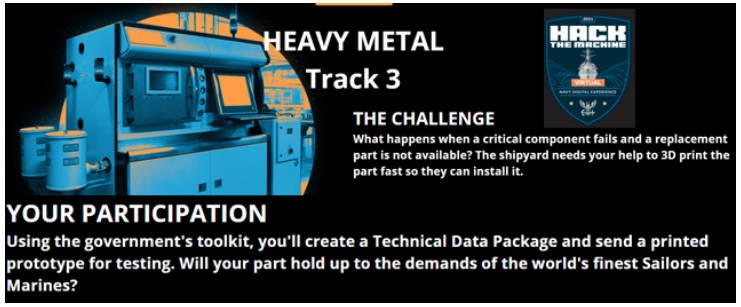
Topic	Maturity			
	Introduced	Outlined	Drafted	Vetted
Terms and Definitions	X			
General Requirements	X	X	X	
Product Requirements	X	X	X	
Inspection Requirements	X	X	X	
End Delivery Requirements	X			
Preservation of Information	X	X		
Data Security	X	X	X	
Data Package Configuration	X	X	X	X

Status

- Next steps
  - Further develop configuration management
  - Complete “X” on tables
- Interest from TC 184 in leveraging data elements for inclusion in future STEP APs
  - Ongoing case study for using STEP AP242e2 and AP238 to drive fabrication
- Preliminary Ballot coming soon

Engage with Stakeholders





DLA expands DOD additive manufacturing tool in fight against COVID-19

By Michael Molinaro, DLA Information Operations

FORT BELVOIR, Va.,

A Defense Logistics Agency tool that consolidates the Defense Department’s technical data packages for advance manufacturing could be a new weapon in the battle against COVID-19.

Common Data Dictionary

- Working Group
- Standard Development
  - Overview of Data Pedigree- WK72172

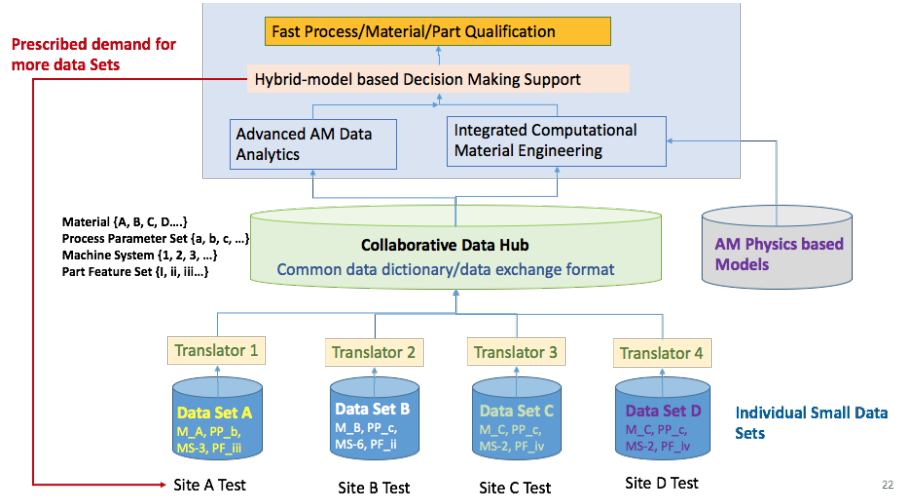
AM Data Management Working Group

- Ad hoc group established during NAMTII 2018 (Nov, 2018)
- Coordinated by National Institute of Standards and Technology
- Scope of the AM Data Management Working group
  - Complete AM Common Data Dictionary (CDD)
  - Develop Common Data Exchange Formats (CDEF)
  - Data Curation and Integration– using CDD and CDEF
    - Exchange data between existing databases
    - Federate data into common repository
  - Feasibility demonstration through qualification use case
- Bi-weekly phone calls every other Monday
- Support from ASTM Center of Excellence
- Frequent face-to-face working meetings

Objective of AM CDD

The objective of the AM CDD is to provide definitions of a common set of concepts, data elements in AM domain which define the basis of AM data collection, integration, management and exchange.

- Use of common data dictionaries supports the ease of data collection, curation, data storage, data discovery and data exchange.
- Build a foundation for the subsequent development of common data exchange formats and standards data governance for a more streamlined AM development lifecycle and value chain management



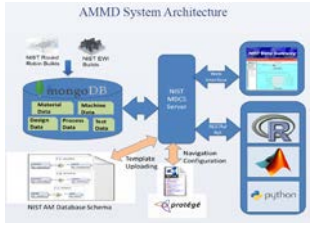
Scope of AM CDD Current Efforts

The audience for this CDD includes:

- AM product users
- AM service provider
- AM machine/material vendors
- AM data management system vendors
- AM data providers

Current AM Common Data Dictionary Scope:

- Powder Bed Fusion processes
- Focus on Logical model
- Class (Entity type) name, attribute/property name
- Limited class depth
- Incremental use scope



NIST AM DATABASE
ammd.nist.gov

GRANTA MI
MATERIAL INTELLIGENCE

MaterialCenter
MSC Software
CITRINE INFORMATICS

And others..

AM CDD Development Timeline

PHASE I

Task 1: First Draft of CDD **Jan. 13, 2020**

Task 2: External review of the first Draft of CDD **Feb. 28, 2020**

Task 3: CDD Harmonization with existing terms/defs standards **Feb. 28, 2020**

Task 4: CDD-based Integrated Query Demonstration **Feb 10, 2020**

Task5: ASTM CDD Standards NWI **March 10, 2020**

Task 6: Internal feedback on the second Draft of CDD on July 25, approved by the working group **July 27, 2020**

Task 8: ASTM CDD Ballot **2020**

Task 7: Share CDD 2.0 (comment/implementation sheet) and WK72172 with Round 1 reviewers/new reviewers; solicit more feedback **~August 7, 2020; returned by August 21**

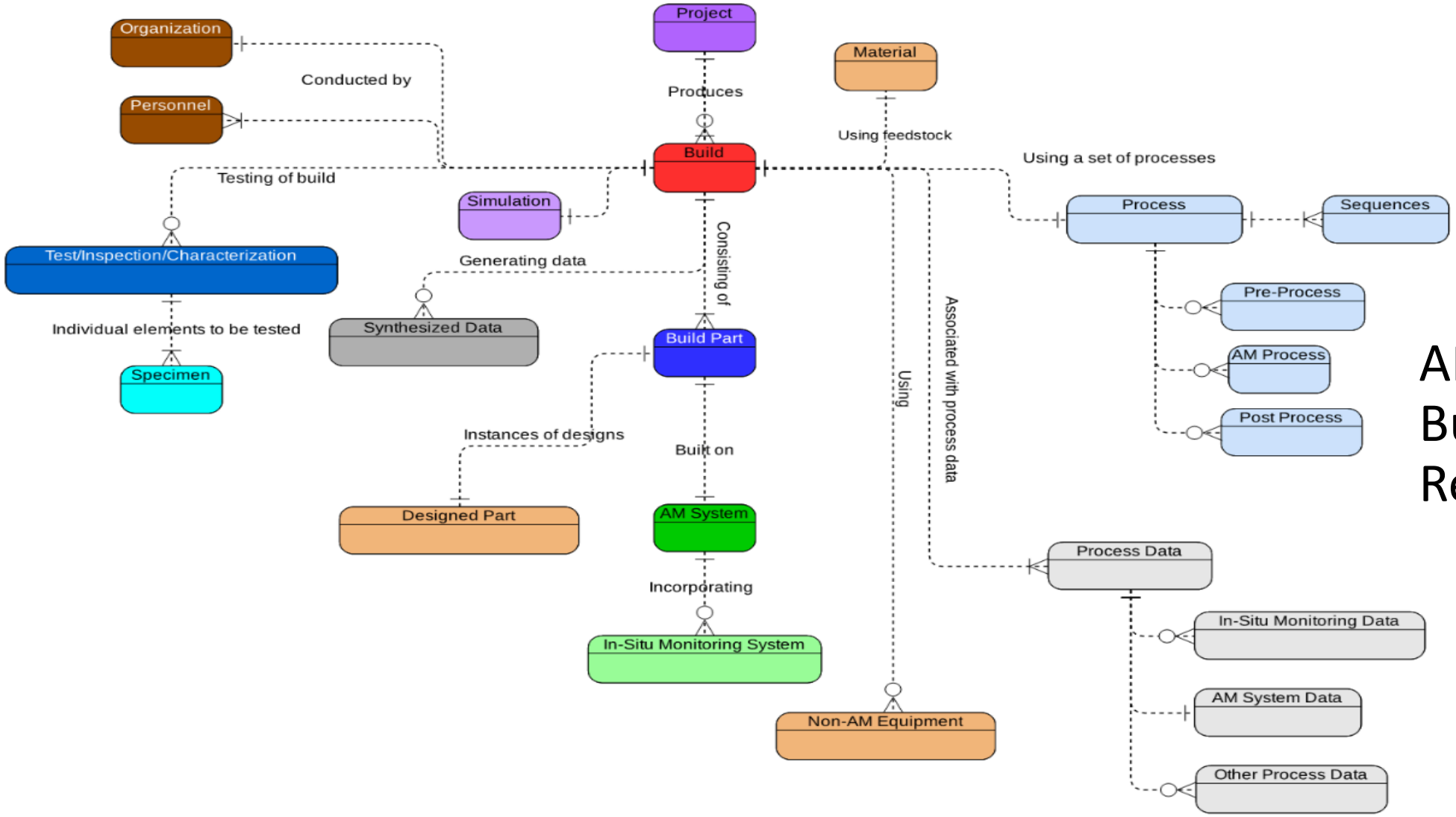
Task 9: ASTM CDD available from NIST website; **2021**

Task 10: ASTM CDD on Mobi; **2021**

PHASE II

- New efforts to transition to Model
- Effort with Power Size Distribution Case Study

Moving from Dictionary to Model



AM Data Bucket/Class Relationship

FAIR AM DATA Workshop October 2020

NIST National Institute of Standards and Technology U.S. Department of Commerce

Pilgrim Consulting - Pathfinding Strategies - Sage Advice

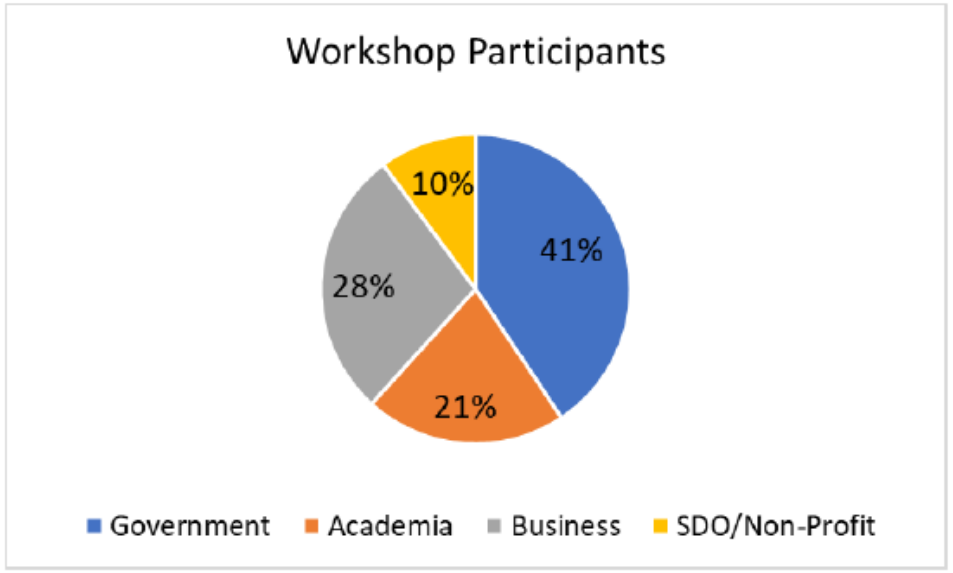
ASM INTERNATIONAL

Findable Accessible Interoperable Reusable AM DATA

Salutation	No.
Dr.	70
Mr.	39
Mrs.	8
Ms.	11

Agenda Item	27 Oct	28 Oct
Total	128	128
Plenary	113	99
Working Groups	68	50
Brief Out Session	n/a	54

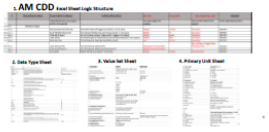
Category	No.
Government	52
Academia	27
Business	36
SDO/Non Profit	13



The FAIR AM Data Workshop Already Impacting Stands Programs

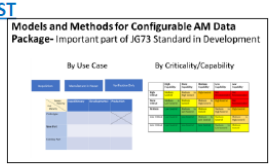
AM Common Data Dictionary

- An ad-hoc AM Data Working Group from 2018
- AM information modules
- Standard definitions of AM data elements, their data types, and allowable values
- AM common data dictionary Excel Sheet
- ASTM F42.08 WK72172
- Contact: Dr. Yan Lu, NIST



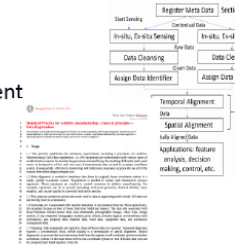
AM Data Package

- ASTM F42 ISO TC 261 JG 73
- Additive Manufacturing— Data Packages for AM Parts
- Contact: Dr. Paul Witherell, NIST



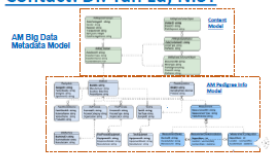
AM Data Registration

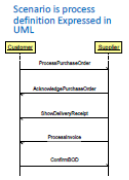
- In-situ/ex-situ data alignment
- Data set metadata
- ASTM F42.08 WK73978
- Contact: Dr. Shaw Feng, NIST



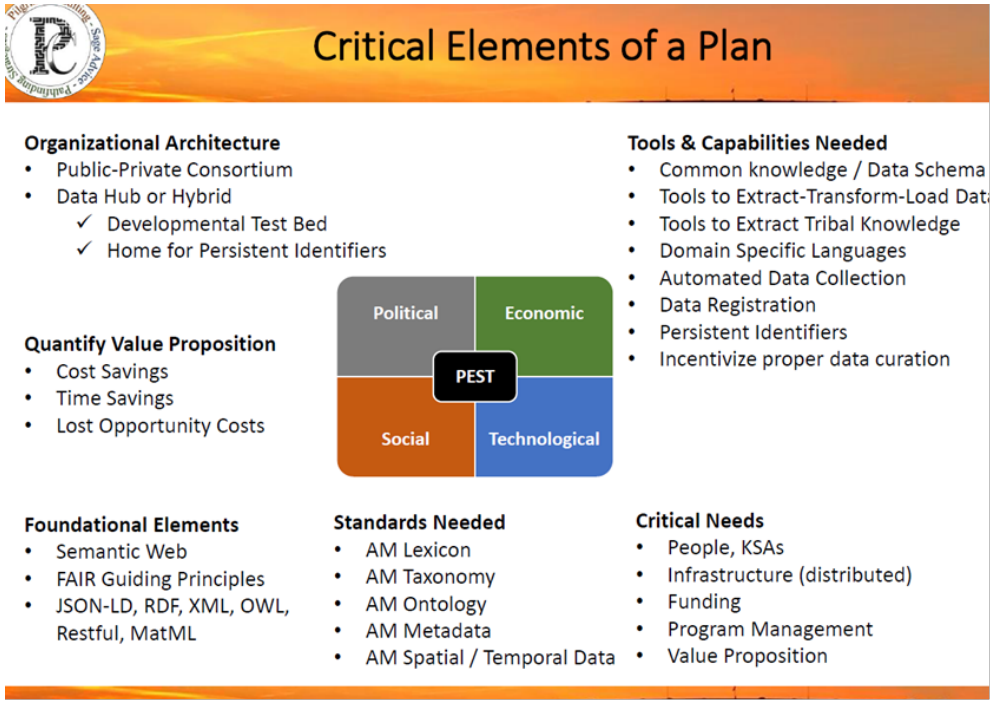
Message-based AM Big Data Exchange

- Open Application Group Integration (OAGI) Specification message for AM Big Data Exchange Message
- Contact: Dr. Yan Lu, NIST





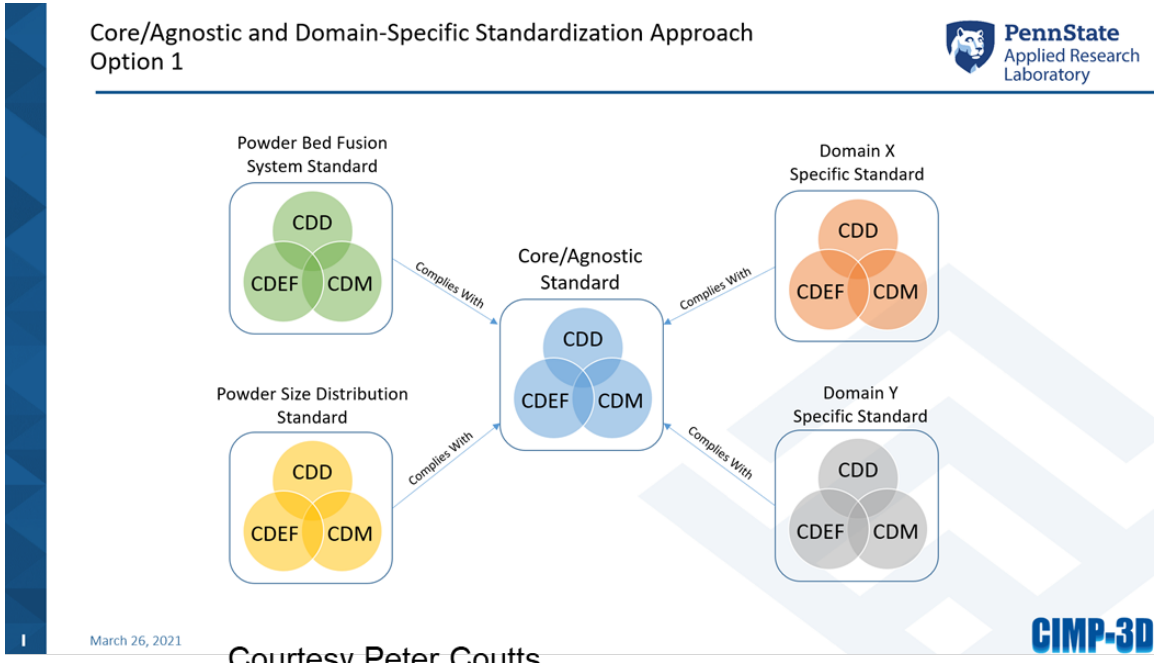
Current State



Courtesy Bill Frazier Pilgrim Consulting

Follow FAIR workshop recommendations moving forward with CDD community

Adopt inheritance approach (including ontology) in development of AM data models



Courtesy Peter Coutts

Thank You

For Data Packages:

Paul Witherell, PhD
paul.witherell@nist.gov
National Institute of Standards and Technology

For CDD:

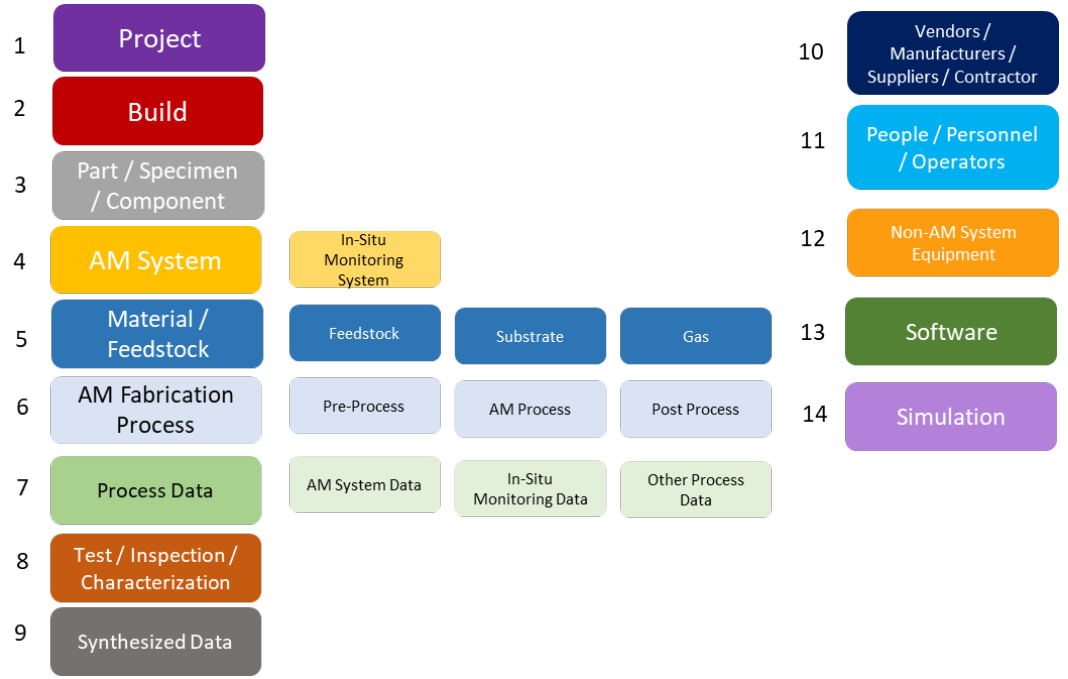
Yan Lu, PhD
yan.lu@nist.gov
National Institute of Standards and Technology

Backup

Role of AM CDD in the TDP?

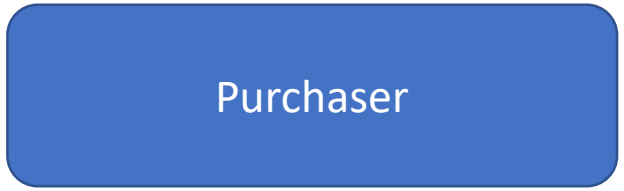
The objective of the AM CDD is to provide definitions of a common set of concepts, data elements in AM domain which define the basis of AM data collection, integration, management and exchange.

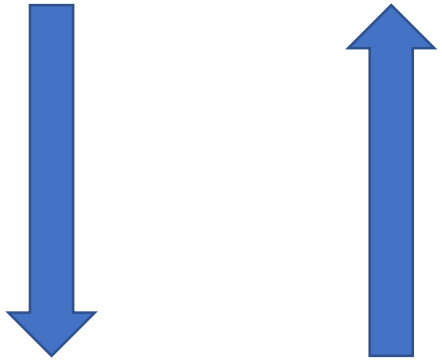
- Use of common data dictionaries supports the ease of data collection, curation, data storage, data discovery and data exchange.
- Build a foundation for the subsequent development of common data exchange formats and standards data governance for a more streamlined AM development lifecycle and value chain management



F42.08 Created- ASTM AM Data Subcommittee

Data Packages:

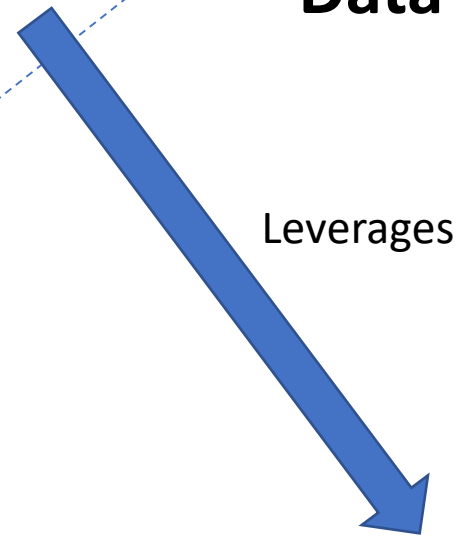




TIDPP+Design Data Package:
Sets Requirements

Reference “language” to set requirements?

Production Data Package:
Certification that parts met requirements



Leverages for data exchange

Data Schema:

Common Data Exchange Format:
Neutral file format that enables exchange of common data dictionary based data

Is built based on

Common Data Dictionary:
Standard terminology and relationships for AM data