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Standard Practice for
Additive Manufacturing — General Principles — Overview of Data Pedigree[1]

This standard is issued under the fixed designation F3490; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The scope of this document outlines the interpretation of additive manufacturing (AM) data. Currently, legacy AM data is stored in different databases or data management systems, each of which uses its own data dictionary. A common data dictionary allows AM data pedigree to be discovered, mapped, federated, and analyzed to improve both the understanding and qualification of AM processes and parts.

1.2 A common data dictionary facilitates the interoperability, searchability, and reusability of AM data by *(1)* identifying the general AM data pedigree elements already defined in a standardized terminology and *(2)* defining those salient terms with indisputable semantics (meanings). The goal of this document is to provide a first subset of the common data dictionary by which AM data may be collected, curated, and shared, regardless of which technology platform and software are used for data storage and exchange.

1.3 The common data dictionary also specifies a way to group AM data pedigree into fifteen information modules pertaining to different aspects of the entire additive manufacturing process.

1.4 The common data dictionary approach specifies data element names that serve to uniquely identify the AM data elements. The data type, value domain, and term definition for each data element are also specified in this practice. References are provided for those data elements with established definitions in existing standards.

1.5 The data elements identified in this common data dictionary are considered essential, because they are most frequently encountered in AM, process agnostic and technology independent. They are broadly applicable to all the process categories defined in ISO/ASTM 52900. It is intended to be a starting point, not all-encompassing.

1.6 The common data dictionary does not specify:

1.6.1 A complete set of data items to be exchanged through AM development lifecycle and value chains.

1.6.2 A minimum set of data items to be exchanged for AM lifecycle and value chain activities.

1.6.3 A common AM data exchange format.

1.6.4 The details associated with how the common descriptions of data items should be implemented for the development of new data systems or data federations among heterogeneous data systems.

1.7 Additional data elements beyond those defined in existing ASTM, ISO, AWS, NASA and SAE standards have been introduced to provide increased utility for AM. These new data items are generally common-sense and frequently used in the AM industry.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A1080 Practice for Hot Isostatic Pressing of Steel, Stainless Steel, and Related Alloy Castings

E1338 Guide for Identification of Metals and Alloys in Computerized Material Property Databases

E2077 Specification for Analytical Data Interchange Protocol for Mass Spectrometric Data

E2339 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)

2.2 *ISO/ASTM Standards:*[2]

52900 Terminology for Additive Manufacturing Technologies

52915 Specification for additive manufacturing file format (AMF) Version 1.2

52921 Terminology for Additive Manufacturing— Coordinate Systems and Test Methodologies

52930 Additive manufacturing qualification principles — Installation, operation and performance (IQ, OQ, PQ) of PBF-LB equipment

2.3 *ISO Standards:*[3]

ISO 5127 Information and documentation — Foundation and vocabulary

ISO/IEC 6523-1 Information technology — Structure for the identification of organizations and organization parts — Part 1: Identification of organization identification schemes

ISO 8601-1 Date and time — Representations for information interchange — Part 1: Basic rules

ISO 11145 Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols

ISO 11161 Lasers and laser-related equipment — Test methods for laser beam widths, divergence angles and beam propagation

ISO/IEC 11179-1 Information technology — Metadata registries (MDR) — Part 1: Framework

ISO/IEC 11179-3 Information technology — Metadata registries (MDR) — Part 3: Registry metamodel and basic attributes — Amendment 1

ISO 11238 Health informatics — Identification of medicinal products — Data elements and structure for the unique identification and exchange of regulated information on substances

ISO/IEC 11404 Information technology — General-Purpose Datatypes (GPD)

ISO/IEC 11578 Information technology — Open Systems Interconnection — Remote Procedure Call (RPC)

ISO 16781 Space systems — Simulation requirements for control system

ISO 19160 Addressing — Part 4: International postal address components and template language

ISO 19165-1 Geographic information — Preservation of digital data and metadata — Part 1: Fundametals

ISO 22745-2 Industrial automation systems and integration — Open technical dictionaries and their application to master data — Part 2: Vocabulary

ISO/IEC 29155 Systems and software engineering – Information technology project performance benchmarking framework

2.4 *SAE Standards:*[4]

SAE AMS 2750 Pyrometric Requirements for Heat Treatments

SAE AMS 7001 Nickel Alloy, Corrosion and Heat-Resistant, Powder for Additive Manufacturing, 62Ni − 21.5Cr − 9.0Mo − 3.65Nb

SAE ARP1917 Rev. A Aerospace Recommended Practice, Clarification of Terms Used in Aerospace Metals Specifications

2.5 *NASA Standards:*[5]

MSFC-STD-3716 Standard for Additively Manufactured Spaceflight Hardware by Laser Powder Bed Fusion in Metal

MSFC-SPEC-3717 Specification for Control and Qualification of Laser Powder Bed Fusion Metallurgical Processes

2.6 *ASME Standard:*[6]

ASME Y14.46 − 2017 Product Definition for Additive Manufacturing

2.7 *AWS Standard:*[7]

AWS D20.1/D20.1M Specification for Fabrication of Metal Components using Additive Manufacturing

3. Terminology

3.1 *Acronyms:*

3.1.1 *CAD*—computer aided design

3.1.2 *DB*—database

3.1.3 *DOD*—Department of Defense

3.1.4 *ID*—identifier

3.1.5 *ITAR*—International Traffic in Arms Regulations

3.1.6 *PLM*—product lifecycle management

3.1.7 *TIC*—test / inspection / characterization

3.1.8 *URI*—uniform resource identifier

3.1.9 *UUID*—universally unique identifier

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *controlled vocabulary, n*—finite set of values that represent the only allowed values for a data item. **ISO 11238:2018**

3.2.2 *data dictionary, n*—formal repository of terms used to describe data. **ISO 19165-1: 2018**

3.2.3 *data element, n*—a unit of information as defined by a single entry in the *data dictionary*. **E2339**

3.2.4 *data element name, n*—a unique name for each data element.

3.2.5 *data type, n*—the kind of data to be included in the data element, such as numbers, character string, and date. **E1338**

3.2.6 *definition, n*—the meaning of a data element defined in a standard or common sense.

3.2.7 *enumerated value domain, n*—value domain that is specified by a list of all its permissible values. **ISO/IEC 11179-3:2013**

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[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

[5] Available from the NASA Technical Standards System at the NASA website www.standards.nasa.gov.

[6] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[7] Available from American Welding Society (AWS), 8669 NW 36 St., #130, Miami, FL 33166-6672, http://www.aws.org.

3.2.8 *permissible value, n*—expression of a value meaning allowed in a specific value domain. **ISO 22745-2:2010**

3.2.9 *unit of measure, n*—actual units in which the associated values are measured. **ISO/IEC 11179-1:2015**

3.2.10 *value, n*—a component of a value field. A value field may consist of one or more of these components. **E2339**

3.2.11 *value domain, n*—set of permissible values with defined unit of measure. **ISO/IEC 11179-1: 2015**

4. Summary of Practice

4.1 The purpose of the common data dictionary is to establish a common lexicon to facilitate the unambiguous exchange of AM information. This language allows AM practitioners to use the same terminology and data types, thereby promoting a common understanding of their data and promoting the ability to share and reuse that data. Both capabilities will ultimately accelerate growth in the AM sector.

4.2 The common data dictionary contains terms and definitions that pertain broadly to a variety of currently used AM processes that include laser powder bed fusion and wire directed energy deposition, among others. Terms and definitions that apply to a specific AM process will be contained in a separate standard practice.

4.3 Each defined element includes the element name, data type, value domain (permissible values or units of measure, or both), and a definition, which is based on a standard reference if one exists. The data element name solidifies the common language around captured data items. The data type represents how the value should be represented in a database; examples include a string, a real, and a hyperlink. Value Range and Value Set both limit the values a data element can take. Primary Unit is prescribed to ensure simplified sharing of data. The scope of this practice includes *(1)* data elements with existing terminology or reporting guideline standards and *(2)* data elements with commonly agreed-upon or intuitive descriptions. Data elements of the former type reference the applicable standard, while those of the second type include a brief description that has undergone reviews by the AM community.

4.4 As this standard continues to evolve, data elements and information modules may be added or amended. It is possible that this will cause datasets to become non-conforming with the latest data pedigree standard practice. A dataset should specify the version of this practice it is conforming to in order to reduce miscommunications.

5. Significance and Use

5.1 This standard can be used by AM data-system developers to design or update a database that meets business and process requirements. The information modules provide a foundation for an AM data structure. Standard definitions of data elements, their data types, and allowable values can be used directly to define the attributes for AM databases.

5.2 This standard is intended for organizations and personnel who wish to share AM data or who develop AM data management systems. The information modules defined in this standard represent a primary set of AM concepts. These concepts can be used to develop a common data model and a common data-exchange format, thereby enabling the transfer of data between different AM data management systems. Since legacy AM data management systems may use different data element definitions, translators will be needed to map their proprietary data into the common data exchange format. This common format will support both exporting from and importing to the original native formats.

5.3 This standard serves as the source for creating common definitions of and representations for all the AM data elements that have been agreed-upon by the community. Previously, standard definitions existed for only a few, high-level, data elements. This limited the ability of organizations to share AM data elements that were not included in those standards. Additionally, most commercially available AM data management software applications used each organization's internally defined data elements, thereby inadvertently hindering the ability to easily share full AM data sets with other organizations' software solutions.

5.4 This standard significantly eases the communication and use of AM data elements across the industry. It does this by providing, in a single location, a common understanding of individual elements within 15 information modules. Each organization can have increased confidence in using and analyzing AM data sets that adhere to this standard, even when those data sets are generated by another organization. This standard will also provide a starting point from which to build a common data format that will facilitate the transfer of AM data sets among those organizations.

5.5 Not all the data elements are applicable to all the use cases. Some of the definitions of the data items are only applicable to certain cases. For example, "Specimen Orientation" and "Specimen Location" are only applicable to specimens extracted from a built part, not powder specimens.

6. Information Modules

6.1 AM data pedigree covers all the phases of AM part-development lifecycle and all nodes of a supply chain. Based on when and where the data is generated, each AM data element can be grouped into information modules. The additive manufacturing data elements presented in this practice are grouped into 15 discrete information modules as shown in Fig. 1. The information modules are defined in this section. Data element definitions are described in Section 7.

6.2 *Project*—A temporary designation when creating one or more unique AM products or AM services (ISO/IEC 29155). This module contains data relating to an entire project, including related builds and information about project execution and administration.

6.3 *Build*—All the information generated during a single, AM process cycle during which one or more components are 'built up' in layers inside the process chamber of the additive manufacturing system (ISO/ASTM 52900). The Build data module acts as a central reference point for all data related to a build. It contains reference links to other modules involved in
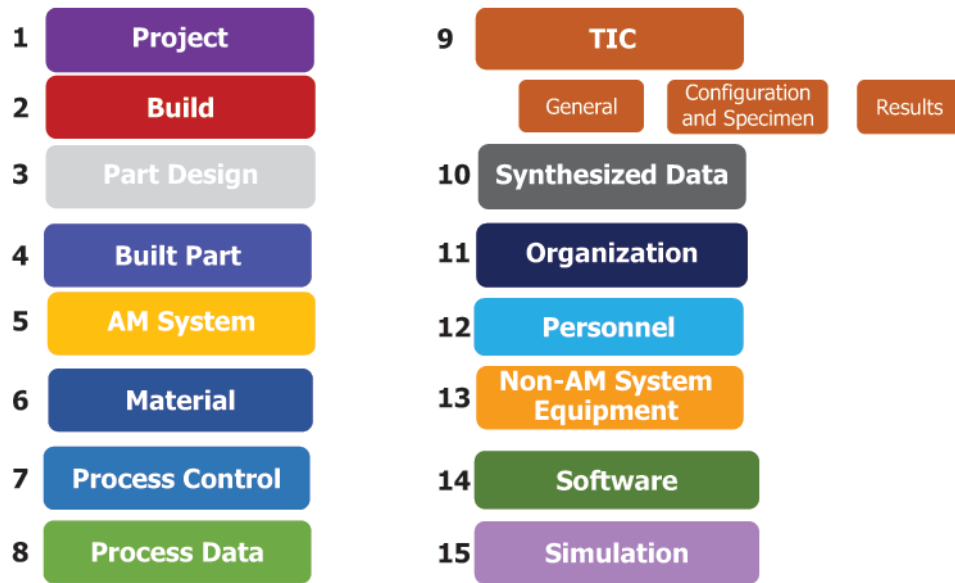
FIG. 1 AM Information Modules

the build process (for example, Material for feedstock information, Parts for information about parts produced in the build).

6.4 *Part Design*—Detailed information associated with the design of a part, including but not limited to an AMF, STL or other 3-D format file, a CAD model, a reverse engineered model, output from medical radiology segmentation software, 3-D modeling, simulation or optimization. Part Design also includes assembly designs. (See ISO/ASTM 52915.)

6.5 *Built Part*—Instances of part or assembly designs in the as-built state. One build can have multiple built parts or assemblies of the same design. This module captures information for parts and assemblies produced by a build.

6.6 *AM System*—AM system includes the AM machine, machine software / firmware and any auxiliary, in situ monitoring equipment used during a build. Manufacturer-provided specifications are included, but details specific to AM process types are omitted.

6.7 *Material*—Details for materials used in the AM process, including feedstock, build platform, and environmental gases; details include order information, characterization, storage details, and more.

6.8 *Process Control*—Controls of the manufacturing processes utilized to produce a certified AM component or part. This module contains process settings and parameters. Elements related to specific, AM-process types are omitted in this practice since they will be defined in separate standards. Post-process settings and parameters are included in this module.

6.9 *Process Data*—The direct data, or derived outputs from that data, is obtained from the AM system and in situ monitoring equipment during a build process. This module captures actual observed and recorded data from a build or the

post processing of that data. Elements related to specific AM process types are omitted in this document; they will be defined in separate standards.

6.10 *Test/Inspection/Characterization (TIC)*—Any inspection or test performed on any material from any stage of the additive manufacturing fabrication process (excluding in-process monitoring). This includes specimen information, the test methodology, and test results. Readers are referred to terminology or reporting guideline standards where applicable.

6.11 *Synthesized Data*—Data that has been reduced from its original raw form and often indicates clearer, more human-friendly, interpretable results. This could include statistical or trend-related results, material cards (for design/simulation), or similar.

6.12 *Organizations*—The organization performing a task or providing services or products. This module details the credentials of vendors, manufacturers, suppliers, and contractors.

6.13 *Personnel*—The individuals performing tasks and their credentials, including their roles, experience, and qualifications.

6.14 *Non-AM Equipment*—This module includes information for non-AM system equipment required for pre-processing, post-processing, tests, inspections, or characterizations, for example, microscopes, sieves, flow meters.

6.15 *Software*—The details of computer programs used during design, AM fabrication processes, analysis, and so forth.

6.16 *Simulation*—The data used and generated from computer programs using physics-based models. This includes information about the models, configurations, and simulation inputs and outputs.

7. Data Element Definitions

NOTE 1—The data elements defined under individual information modules are listed and described in this section.

7.1 *Data Type and Common Value Set Definition*—The data types and common value sets used by the data element definitions are captured in Tables 1 and 2.

7.2 *Project*—See Table 3.

7.3 *Build*—See Table 4.

7.4 *Part Design*—See Table 5.

7.5 *Built Part*—See Table 6.

7.6 *AM System*—See Tables 7 and 8.

7.7 *Material*—See Tables 9 and 10.

7.8 *Process Control*—See Tables 11 and 12.

7.9 *Process Data*—See Tables 13 and 14.

7.10 *Test / Inspection / Characterization*—This section is broken into several sub-sections to help organize the data elements and avoid duplication of common or general data elements that apply to a multitude of tests, inspections, and characterizations. The Test, Inspection, and Characterization group is sometimes referred in general as "TIC".

7.10.1 *General Information*—See Table 15.

7.10.2 *Configuration and Specimen Information*—See Table 16.

7.10.3 *Test Results*—See Table 17.

7.10.4 *Test / Inspection / Characterization Value Sets*—See Table 18.

7.11 *Synthesized Data*—See Tables 19 and 20.

7.12 *Organizations*—See Tables 21 and 22.

7.13 *Personnel*—See Table 23.

7.14 *Non-AM Equipment*—See Table 24.

7.15 *Software*—See Table 25.

7.16 *Simulation*—See Table 26.

8. Keywords

8.1 additive manufacturing; data dictionary; data exchange; data format; data pedigree

TABLE 1 List of the Data Types Used by This Standard

Data Type	Definition	Standard
integer	The mathematical datatype comprising the exact integral values	XSD, ISO/IEC 11404
string	String data types are used for values that contains character strings	XSD
stringArray	An array of strings	
real	Real is a family of datatypes, which are computational approximations to the mathematical datatype that comprises the "real numbers". Specifically, each real datatype designates a collection of mathematical real values, which are expressed in some finite precision and must be distinguishable to at least that precision.	ISO/IEC 11404
date	The date data type is used to specify a date. The date is specified in the following form "YYYY-MM-DD (Time Zone)"	ISO 8601; XSD
dateTime	The dateTime data type is used to specify a date and a time. The dateTime is specified in the following form "YYYY-MM-DDThh:mm:ss (Time Zone)"	ISO 8601; XSD
duration	The duration data type is used to specify a time interval. The time interval is specified in the following form "PnYnMnDTnHnMnS" where: P indicates the period (required) nY indicates the number of years nM indicates the number of months nD indicates the number of days T indicates the start of a time section (required if you are going to specify hours, minutes, or seconds) nH indicates the number of hours nM indicates the number of minutes nS indicates the number of seconds	ISO 8601; XSD
time	The time data type is used to specify a time. hh:mm:ss (Time Zone)	ISO 8601; XSD
anyURI	A data type used to specify a URI	XSD
3dCoordinate	(x, y, z) as real numbers defined in a coordinate system	N/A
globalAddressFormat	International address specified by ISO 19160 includes: Full name, street address, city, state/province/region and country name place, and zip code	ISO 19160-4:2017
document	Recorded information or material object, which can be treated as a unit in a documentation process	ISO 5127:2017

TABLE 2 Common Value Sets Defined Across the 15 Information Modules

Value Set Name	Definition	Definition Source
Process Atmosphere Type Enumeration	{Argon, Helium, CO_2, Oxygen, Nitrogen, Others}	N/A
Pass Fail Enumeration	{pass, fail}	

TABLE 3 Data Elements in the Project Information Module

Data Element Name	Data Type	Value Range, Value Set, or Primary Units	Definition / Standard
Project ID	string	free text (unique)	Identifier of a project. This field is required to be unique across all instances of data records.
Project Creator	string	Organization ID	Organization that created the project
Project Sponsor	string	Organization ID	Provider of money and requirements for the project
Project Distribution Statement	string	Selection of standard DOD distribution statements	Documentation of any access restrictions to the distribution of data collected and analyzed under this project, by organizations other than the authoritative source
Project Distribution Control	string	free text	ITAR, copyright, patent. and other IP licensing declarations, for example, restrictions
Project Start Date	date	The date is specified in the following form "YYYY-MM-DD (Time Zone)"	Start date of a project
Project End Date	date	The date is specified in the following form "YYYY-MM-DD (Time Zone)"	End date of a project
Project Delivery Date	date	The date is specified in the following form "YYYY-MM-DD (Time Zone)"	Delivery date of a project
Project Plan	anyURI	hyperlink	Document describing how a project is to be conducted, organized, and so forth
Project Owning Materials DB	string	free text (unique)	A unique identifier (or equivalent) to identify the authoritative Materials DB that houses this project and all corresponding data
Project Repository	anyURI	hyperlink	Link or reference to the host system (product lifecycle management repository or database), which houses the authoritative data in this data set
Project Builds	stringArray	Build ID	List of identifiers to builds associated to this project
Project Standards	string	free text	Set of standards used in the project
Project Quality Control Plan	anyURI	hyperlink	Document describing the quality control plan for the site performing the project
Project Quality Process Control Plan	anyURI	hyperlink	Document describing the quality process control plan for the site performing the project

TABLE 4 Data Elements in the Build Information Module

Data Element Name	Data Type	Value Range, Value Set, or Primary Units	Definition / Standard
Build ID	string	free text (unique)	Identifier for an AM build; This field is required to be unique across all instances of data records
Project ID	string	Project ID	Reference to the associated project that produced this build. Links to a Project record.
AM System ID list	stringArray	AM System ID	Reference to the associated AM system(s) for this build. Links to a list of AM System records.
Part Design ID list	stringArray	Part Design ID	Reference to the part designs used for this build. Links to Part Design records.
Built Part ID list	stringArray	Built Part ID	Reference to set of Built Parts that are incorporated into this build. Links to Built Part records.
Process ID list	stringArray	Process ID	Reference to Processes associated with the entire build. Links to a list of Process records. Individual, Built Part records will have part-specific processes associated with them.
Specimen ID list	stringArray	Specimen ID	List of Specimens associated with this build. Links to a set of Specimen records.
Process Data ID list	stringArray	Process Data ID	Reference to list of Process Data records for data gathered during this build
TIC ID list	stringArray	TIC IDs	Reference to list of test/inspection/characterization records associated to the whole build (TIC performed on built parts or specimens would be linked from those records)
Simulation ID list	stringArray	Simulation ID	Reference to Simulation records associated to this build. Links to a list of Simulation records.
Software ID list	stringArray	Software ID	Reference to list of software used in build. Links to Software records.
Organization ID	string	Organization ID	Reference to production Organization for this build. Links to an Organization record.
NonAMEquip ID list	stringArray	NonAMEquip ID	Reference to list of Non-AM Equipment records. Links to NonAM Equipment record.
Material ID list	stringArray	Material ID	Reference to material feedstock records for build. Links to Material records.
Build Personnel	stringArray	Personnel ID	Reference to personnel associated with the build (that is, operators, inspectors). Links to Personnel records.
SynthData ID list	stringArray	SynthData ID	Reference to Synthesized Data records associated to this build
Build Plan	string/anyURI	free text or hyperlink	Document that describes the specific, build-design intent and requirements, which must include specified dimensional unit of measure, accuracy (number of digits), and precision (tolerance of ±), for build parts and assemblies. This may include platform layout, witness coupons, object quantity, and position/orientation.
Build Platform Definition	string/anyURI	free text or hyperlink	File that describes the contents of the build platform (objects and locations). This is intended to be a CAD file that models the build platform and individual component layouts, that would be fed to the AM System processing software to perform the build.
Build Type	string	free text	Description of the primary purpose of the Build (end use component, specimens, research, and so forth)
Build Platform	string	Build Platform ID	Unique identifier to associate a physical build platform with a Build record
Build Job File	anyURI	hyperlink	File (or pointer to file) containing the build job defined by the machine