Standard Terminology for Additive Manufacturing – General Principles – Terminology[1,2]

This standard is issued under the fixed designation ISO/ASTM 52900; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision.

1. Scope

1.1 This International Standard establishes and defines terms used in additive manufacturing (AM) technology, which applies the additive shaping principle and thereby builds physical 3D geometries by successive addition of material.

1.2 The terms have been classified into specific fields of application.

1.3 New terms emerging from the future work within ISO/TC 261 and ASTM F42 will be included in upcoming amendments and overviews of this International Standard.

2. Referenced Documents

2.1 *ISO Standards:*[3]

ISO 841 Industrial automation systems and integration—Numerical control of machines—Coordinate system and motion nomenclature

ISO 10303 Industrial automation systems and integration—Product data representation and exchange

ISO 17296-2 Additive manufacturing—General priniciples—Part 2: Overview of process categories and feedstock

2.2 *ISO/ASTM Standards:*[3,4]

ISO/ASTM 52915 Standard specification for additive manufacturing file format (AMF)

ISO/ASTM 52921 Terminology for Additive Manufacturing—Coordinate Systems and Test Methodologies

3. Terminology

3.1 *General Terms*

3D printer, *n*—machine used for **3D printing**.

additive manufacturing (AM), *n*—process of joining materials to make **parts** from 3D model data, usually **layer** upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies.

Discussion—Historical terms: additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing, solid freeform fabrication and freeform fabrication.

Discussion—The meaning of "additive", "subtractive" and "formative" manufacturing methodologies are further discussed in Annex A1.

additive system, *n*—**additive manufacturing system**, additive manufacturing equipment, machine and auxiliary equipment used for **additive manufacturing**.

AM machine, *n*—section of the **additive manufacturing system** including hardward, machine control software, required set-up software and peripheral accessories necessary to complete a **build cycle** for producing **parts**.

AM machine user, *n*—operator of or entity using an **AM machine**.

AM system user, *n*—additive system user, operator of or entity using an entire **additive manufacturing system** or any component of an additive system.

front, *n—of a machine, unless otherwise designated by the machine builder*, side of the machine that the operator faces to access the user interface or primary viewing window, or both.

material supplier, *n*—provider of material/**feedstock** to be processed in **additive manufacturing system**.

multi-step process, *n*—type of **additive manufacturing** process in which **parts** are fabricated in two or more operations where the first typically provides the basic geometric shape and the following consolidates the part to the fundamental properties of the intended material (metallic, ceramic, polymer or composite).

Discussion—Removal of the support structure and cleaning may be necessary; however, in this context not considered as a separate process step.

[1] This international standard is under the jurisdiction of Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.91 on Terminology, and is also under the jurisdiction of ISO/TC 261.

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[2] Through a mutual agreement with ASTM International (ASTM), the Society of Manufacturing Engineers (SME) contributed the technical expertise of its RTAM Community members to ASTM to be used as the technical foundation for this ASTM standard. SME and its membership continue to play an active role in providing technical guidance to the ASTM standards development process.

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

[4] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

Discussion—The principle of **single-step** and multi-step processes are further discussed in Annex A1.

single-step process, *n*—type of **additive manufacturing** process in which **parts** are fabricated in a single operation where the basic geometric shape and basic material properties of the intended product are achieved simultaneously.

Discussion—Removal of the support structure and cleaning may be necessary; however, in this context not considered as a separate process step.

Discussion—The principle of single-step and **multi-step processes** are further discussed in Annex A1.

3.2 *Process Categories*

binder jetting, *n*—**additive manufacturing** process in which a liquid bonding agent is selectively deposited to join powder materials.

directed energy deposition, *n*—**additive manufacturing** process in which focused thermal energy is used to fuse materials by melting as they are being deposited.

Discussion—"Focused thermal energy" means that an energy source (e.g., laser, electron beam, or plasma arc) is focused to melt the materials being deposited.

material extrusion, *n*—**additive manufacturing** process in which material is selectively dispensed through a nozzle or orifice.

material jetting, *n*—**additive manufacturing** process in which droplets of build material are selectively deposited.

Discussion—Example materials include photopolymer and wax.

powder bed fusion, *n*—**additive manufacturing** process in which thermal energy selectively fuses regions of a **powder bed**.

sheet lamination, *n*—**additive manufacturing** process in which sheets of material are bonded to form a **part**.

vat photopolymerization, *n*—**additive manufacturing** process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization.

3.3 *Processing: General*

3D printing, *n*—fabrication of objects through the deposition of a material using a print head, nozzle, or another printer technology.

Discussion—Term often used in a non-technical context synonymously with **additive manufacturing**; until present times this term has in particular been associated with machines that are low end in price and/or overall capability.

build chamber, *n*—enclosed location within the **additive manufacturing system** where the **parts** are fabricated.

build cycle, *n*—single process cycle in which one or more components are built up in **layers** in the process chamber of the **additive manufacturing system**.

build envelope, *n*—largest external dimensions of the x-, y-, and z-axes within the **build space** where **parts** can be fabricated.

Discussion—The dimensions of the build space will be larger than the build envelope.

build platform, *n—of a machine*, base which provides a surface upon which the building of the **part/s** is started and supported throughout the build process.

Discussion—In some systems the **parts** are built attached to the build platform, either directly or through a support structure. In other systems, such as **powder bed** systems, no direct mechanical fixture between the build and the platform may be required.

build space, *n*—location where it is possible for **parts** to be fabricated, typically within the **build chamber** or on a **build platform**.

build surface, *n*—area where material is added, normally on the last deposited **layer** which becomes the foundation upon which the next layer is formed.

Discussion—For the first layer, the build surface is often the **build platform**.

Discussion—In the case of **directed energy deposition processes**, the build surface can be an existing part onto which material is added.

Discussion—If the orientation of the material deposition or consolidation means, or both, is variable, it may be defined relative to the build surface.

build volume, *n*—total usable volume available in the machine for building **parts**.

feed region, *n—in* **powder bed fusion**, location/s in the machine where **feedstock** is stored and from which a portion of the feedstock is repeatedly conveyed to the powder bed during the **build cycle**.

layer, *n*—matter material laid out, or spread, to create a surface.

machine coordinate system, *n*—three-dimensional coordinate system as defined by a fixed point on the **build platform** with the three principal axes labelled x-, y-, and z-, with rotary axis about each of these axis labelled A, B, and C, respectively, where the angles between x-, y- and z- can be Cartesian or defined by the machine manufacturer.

Discussion—Machine coordinate system is fixed relative to the machine, as opposed to coordinate systems associated with the **build surface** which can be translated or rotated. Machine coordinate system is illustrated in ISO/ASTM 52921.

manufacturing lot, *n*—set of manufactured **parts** having commonality between **feedstock**, **production run**, **additive manufacturing system**, and **post-processing** steps (if required) as recorded on a single manufacturing work order.

Discussion—**Additive manufacturing system** could include one or several **AM machines** and/or **post-processing** machine units, as agreed by **AM** provider and customer.

origin, *n*—zero point, (0, 0, 0), *when using x-, y-, and z-coordinates*, designated universal reference point at which the three primary axes in a coordinate system intersect.

Discussion—Coordinate system can be Cartesian or as defined by the machine manufacturer. The concept of origin is illustrated in ISO/ASTM 52921.

build origin, n—**origin** most commonly located at the centre of the **build platform** and fixed on the build facing surface, but could be defined otherwise by the build set-up.

machine origin, n—machine home, machine zero point, **origin** as defined by the machine manufacturer.

overflow region, *n—in* **powder bed fusion** *systems*, location/s in the machine where excess powder is stored during a **build cycle**.

DISCUSSION—For certain machine types the overflow region may consist of one or more dedicated chambers or a powder recycling system.

part location, *n*—location of the **part** within the **build volume**.

DISCUSSION—The part location is normally specified by the x-, y- and z-coordinates for the position of the **geometric centre** of the part's **bounding box** with respect to the **build volume**, **origin**. Part location is illustrated in ISO/ASTM 52921

process parameters, *n*—set of operating parameters and system settings used during a single **build cycle**.

production run, *n*—all **parts** produced in one **build cycle** or sequential series of build cycles using the same **feedstock** batch and process conditions.

system set-up, *n*—configuration of the **additive manufacturing system** for a build.

x-axis, *n—of a machine, unless otherwise designated by the machine builder*, axis in the **machine coordinate system** that runs parallel to the **front** of the machine and perpendicular to the **y-axis** and **z-axis**.

DISCUSSION—Unless otherwise designated by the machine builder, the positive x-direction runs from left to right as viewed from the front of the machine while facing toward the **build volume origin**.

DISCUSSION—It is common that the x-axis is horizontal and parallel with one of the edges of the **build platform**.

y-axis, *n—of a machine, unless otherwise designated by the machine builder*, axis in the **machine coordinate system** that runs perpendicular to the **z-axis** and **x-axis**.

DISCUSSION—Unless otherwise designated by the machine builder, the positive direction is defined in ISO 841 to make a right hand set of coordinates. In the most common case of an upwards z-positive direction, the positive y-direction will then run from the front to the back of the machine as viewed from the front of the machine.

DISCUSSION—In the case of building in the downwards z-positive direction, the positive y-direction will then run from the back of the machine to the front as viewed from the front of the machine.

DISCUSSION—It is common that the y-axis is horizontal and parallel with one of the edges of the **build platform**.

z-axis, *n—of a machine; unless otherwise designated by the machine builder*, axis in the **machine coordinate system** that run perpendicular to the **x-axis** and **y-axis**.

DISCUSSION—Unless otherwise designated by the machine builder, the positive direction is defined in ISO 841 to make a right hand set of coordinates. For processes employing planar, layerwise addition of material, the positive z-direction will then run normal to the **layers**.

DISCUSSION—For processes employing planar layerwise addition of material, the positive z-direction, is the direction from the first layer to the subsequent layers.

DISCUSSION—Where addition of material is possible from multiple directions (such as with certain **directed energy deposition** systems), the z-axis may be identified according to the principles in ISO 841, (4.3.3) which addresses "swivelling or gimballing."

3.4 *Processing: Data*

3D scanning, *n*—3D digitizing, method of acquiring the shape and size of an object as a 3-dimensional representation by recording x,y,z coordinates on the object's surface and through software the collection of points is converted into digital data.

DISCUSSION—Typical methods use some amount of automation, coupled with a touch probe, optical sensor, or other device.

Additive Manufacturing File Format (AMF), *n*—file format for communicating **additive manufacturing** model data including a description of the 3D surface geometry with native support for colour, materials, lattices, textures, constellations and metadata.

DISCUSSION—Additive Manufacturing File Format (AMF) can represent one of multiple objects arranged in a constellation. Similar to **STL** the surface geometry is represented by a triangular mesh, but in **AMF** the triangles may also be curved. **AMF** can also specify the material and colour of each volume and the colour of each triangle in the mesh. ISO/ASTM 52915 gives the standard specification of **AMF**.

bounding box, *n—of a part*, orthogonally oriented minimum perimeter cuboid that can span the maximum extents of the points on the surface of a 3D **part**.

DISCUSSION—Where the manufactured part includes the test geometry plus additional external features (for example, labels, tabs or raised lettering), the bounding box may be specified according to the test part geometry excluding the additional external features if noted. Different varieties of bounding boxes are illustrated in ISO/ASTM 52921.

arbitrarily oriented bounding box, n—of a **part**, **bounding box** calculated without any constraints on the resulting orientation of the box.

machine bounding box, n—of a **part**, **bounding box** for which the surfaces are parallel to the **machine coordinate system**.

master bounding box, n—**bounding box** which encloses all of the **parts** in a single build.

extensible markup language, XML, *n*—standard from the WorldWideWeb Consortium (W3C) that provides for tagging of information content within documents offering a means for representation of content in a format that is both human and machine readable.

DISCUSSION—Through the use of customizable style sheets and schemas, information can be represented in a uniform way, allowing for interchange of both content (data) and format (metadata).

facet, *n*—typically a three- or four-sided polygon that represents an element of a 3D polygonal mesh surface or model.

DISCUSSION—Triangular facets are used in the file formats most significant to **AM**: **AMF** and **STL**; however, **AMF** files permits a triangular facet to be curved.

geometric centre, *n*—centroid, *of a bounding box*, location at the arithmetic middle of the **bounding box** of the **part**.

DISCUSSION—The centre of the bounding box could lie outside the part.

IGES, *n*—Initial Graphics Exchange Specification, platform neutral CAD data exchange format intended for exchange of product geometry and geometry annotation information.

Discussion—IGES is the common name for a United States National Bureau of Standards standard NBSIR 80-1978, Digital Representation for Communication of Product Definition Data, which was approved by ANSI first as ANS Y14.26M-1981 and later as ANS USPRO/IPO-100-1996. IGES version 5.3 was superseded by ISO 10303, **STEP** in 2006.

initial build orientation, *n—of a* **part**, orientation of the part as it is first placed in the **build volume**.

Discussion—Initial build orientation is illustrated in ISO/ASTM 52921.

nesting—situation when **parts** are made in one **build cycle** and are located such that their **bounding boxes**, **arbitrarily oriented** or otherwise, will overlap.

PDES, *n*—Product Data Exchange Specification or Product Data Exchange using **STEP**.

Discussion—Originally, a product data exchange specification developed in the 1980s by the IGES/PDES Organization, a program of US Product Data Association (USPRO). It was adopted as the basis for and subsequently superseded by ISO 10303 STEP.

part reorientation, *n*—rotation around the **geometric centre** of the part's **bounding box** from the specified **initial build orientation** of that **part**.

Discussion—Part reorientation is illustrated in ISO/ASTM 52921.

STEP, *n*—standard for the exchange of product model data.

Discussion—ISO standard that provides a representation of product information, along with the necessary mechanisms and definitions to enable product data to be exchanged. ISO 10303 applies to the representation of product information, including components and assemblies; the exchange of product data, including storing, transferring, accessing and archiving.

STL, *n*—file format for model data describing the surface geometry of an object as a tessellation of triangles used to communicate 3D geometries to machines in order to build physical **parts**.

Discussion—The STL file format was originally developed as part of the CAD package for the early STereoLithography Apparatus, thus referring to that process. It is sometimes also described as "Standard Triangulation Language" or "Standard Tesselation Language", though it has never been recognized as an official standard by any standardization organization.

surface model, *n*—mathematical or digital representation of an object as a set of planar or curved surfaces, or both, that can, but does not necessarily have to, represent a closed volume.

3.5 *Processing: Material*

curing, *v*—chemical process which results in the ultimate properties of a finish or other material.

feedstock, *n*—(Deprecated: source material, starting material, base material, original material) bulk raw material supplied to the **additive manufacturing** building process.

Discussion—For additive manufacturing building processes, the bulk raw material is typically supplied in various forms such as liquid, powder, suspensions, filaments, sheets etc.

fusion, *n*—act of uniting two or more units of material into a single unit of material.

laser sintering, LS, *n*—**powder bed fusion** process used to produce objects from powdered materials using one or more lasers to selectively fuse or melt the particles at the surface, **layer** upon layer, in an enclosed chamber.

Discussion—Most LS machines partially or fully melt the materials they process. The word "sintering" is a historical term and a misnomer, as the process typically involves full or partial melting, as opposed to traditional powdered metal sintering using a mould and heat and/or pressure.

part cake, *n—in a* **powder bed fusion** process that uses a heated **build chamber**, lightly bound powder surrounding the fabricated **parts** at the end of a **build cycle**.

post-processing, *n—one or more*, process steps taken after the completion of an **additive manufacturing build cycle** in order to achieve the desired properties in the final product.

powder batch, *n*—powder used as **feedstock** which could be **used powder**, **virgin powder** or a blend of the two.

Discussion—A powder batch could be used in one or more production runs using different process parameters.

powder bed, *n*—part bed, build area in an **additive manufacturing system** in which **feedstock** is deposited and selectively fused by means of a heat source or bonded by means of an adhesive to build up **parts**.

powder blend, *n*—quantity of powder made by thoroughly intermingling powders originating from one or several **powder lots** of the same nominal composition.

Discussion—A common type of powder blend consists of a combination of **virgin powder** and **used powder**. The specific requirements for a powder blend are typically determined by the application, or by agreement between the supplier and end-user.

Discussion—In traditional powder metallurgy, a distinction is made between blended powders and mixed powders, in which case blended powders are combinations of powders with nominally identical composition, whereas mixed powders are combinations of powders with different compositions.

powder lot, *n*—quantity of powder produced under traceable, controlled conditions, from a single powder manufacturing process cycle.

Discussion—The size of a powder lot is defined by the powder supplier. It is common that the powder supplier distributes a portion of a powder lot to multiple **AM system users**.

Discussion—Source documentation of the powder lot is normally required for most **AM** product applications. Source documentation is also referred to as a "certificate of conformance", "factory certificate" or "certificate of analysis".

used powder, *n*—powder that has been supplied as **feedstock** to an **AM machine** during at least one previous **build cycle**.

virgin powder, *n*—unused powder from a single **powder lot**.

3.6 *Applications*

part, *n*—joined material forming a functional element that could constitute all or a section of an intended product.

Discussion—The functional requirements for a part are typically determined by the intended application.

prototype, *n*—physical representation of all or a component of a product that, although limited in some way, can be used for analysis, design and evaluation.