



# Standard Terminology for Additive Manufacturing Technologies<sup>1,2</sup>

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## 1. Scope

1.1 This terminology includes terms, definitions of terms, descriptions of terms, nomenclature, and acronyms associated with additive-manufacturing (AM) technologies in an effort to standardize terminology used by AM users, producers, researchers, educators, press/media and others.

NOTE 1—The subcommittee responsible for this standard will review definitions on a three-year basis to determine if the definition is still accurate as stated. Revisions will be made when determined to be necessary.

## 2. Referenced Documents

### 2.1 ISO Standard:<sup>3</sup>

ISO 10303 -1:1994 Industrial automation systems and integration -- Product data representation and exchange -- Part 1: Overview and fundamental principles

## 3. Significance and Use

3.1 The definitions of the terms presented in this standard were created by this subcommittee. This standard does not purport to address safety concerns associated with the use of AM technologies. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use of additive manufacturing.

## 4. Additive Manufacturing Process Categories

4.1 The following terms provide a structure for grouping current and future AM machine technologies. These terms are useful for educational and standards-development purposes and are intended to clarify which machine types share process-

ing similarities. For many years, the additive manufacturing industry lacked categories for grouping AM technologies, which made it challenging educationally and when communicating information in both technical and non-technical settings. These process categories enable one to discuss a category of machines, rather than needing to explain an extensive list of commercial variations of a process methodology.

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

**directed energy deposition**, *n*—an 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*—an additive manufacturing process in which material is selectively dispensed through a nozzle or orifice.

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

DISCUSSION—Example materials include photopolymer and wax.

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

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

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

## 5. Terminology

### 5.1 Definitions:

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

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

DISCUSSION—Term often used synonymously with additive manufacturing; in particular associated with machines that are low end in price and/or overall capability.

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<sup>2</sup> 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.

<sup>3</sup> Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, [http://www.iso.org/iso/iso\\_catalogue/catalogue\\_tc/catalogue\\_detail.htm?csnumber=20579](http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=20579)

**3D scanning**, *n*—a 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. Synonym: 3D digitizing.

**additive manufacturing (AM)**, *n*—a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. Synonyms: additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing, and freeform fabrication.

**additive systems**, *n*—machines used for additive manufacturing.

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

**direct metal laser sintering (DMLS®)**, *n*—a powder bed fusion process used to make metal parts directly from metal powders without intermediate “green” or “brown” parts; term denotes metal-based laser sintering systems from EOS GmbH - Electro Optical Systems. Synonym: direct metal laser melting.

**directed energy deposition**, *n*—an 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.

**facet**, *n*—typically a three- or four-sided polygon that represents an element of a 3D polygonal mesh surface or model; triangular facets are used in STL files.

**fused deposition modeling (FDM®)**, *n*—a material extrusion process used to make thermoplastic parts through heated extrusion and deposition of materials layer by layer; term denotes machines built by Stratasys, Inc.

**laser sintering (LS)**, *n*—a 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 by 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 mold and heat and/or pressure.

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

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

DISCUSSION—Example materials include photopolymer and wax.

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

**prototype tooling**, *n*—molds, dies, and other devices used to produce prototypes; sometimes referred to as bridge tooling or soft tooling.

**rapid prototyping**, *n*—additive manufacturing of a design, often iterative, for form, fit, or functional testing, or combination thereof.

**rapid tooling**, *n*—the use of additive manufacturing to make tools or tooling quickly, either directly, by making parts that serve as the actual tools or tooling components, such as mold inserts, or indirectly, by producing patterns that are, in turn, used in a secondary process to produce the actual tools.

**rapid tooling**, *n*—*in machining processes*, the production of tools or tooling quickly by subtractive manufacturing methods, such as CNC milling, etc.

**reverse engineering**, *n*—*in additive manufacturing*, method of creating a digital representation from a physical object to define its shape, dimensions, and internal and external features.

**selective laser sintering (SLS®)**, *n*—denotes the LS process and machines from 3D Systems Corporation.

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

**stereolithography (SL)**, *n*—a vat photopolymerization process used to produce parts from photopolymer materials in a liquid state using one or more lasers to selectively cure to a predetermined thickness and harden the material into shape layer upon layer.

**stereolithography apparatus (SLA®)**, *n*—denotes the SL machines from 3D Systems Corporation.

**subtractive manufacturing**, *n*—making objects by removing of material (for example, milling, drilling, grinding, carving, etc.) from a bulk solid to leave a desired shape, as opposed to additive manufacturing.

**surface model**, *n*—a mathematical or digital representation of an object as a set of planar or curved surfaces, or both, that may or may not represent a closed volume.

DISCUSSION—May consist of Bezier B-spline surfaces or NURBS surfaces. A surface model may also consist of a mesh of polygons, such as triangles, although this approach approximates the exact shape of the model.

**tool, tooling**, *n*—a mold, die, or other device used in various manufacturing and fabricating processes such as plastic injection molding, thermoforming, blow molding, vacuum casting, die casting, sheet metal stamping, hydroforming, forging, composite lay-up tools, machining and assembly fixtures, etc.

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

### 5.2 Acronyms:

**CAD**, *n*—Computer-Aided Design. The use of computers for the design of real or virtual objects.

**CAM, *n***—Computer-Aided Manufacturing. Typically refers to systems that use surface data to drive CNC machines, such as digitally-driven mills and lathes, to produce parts, molds, and dies.

**CNC, *n***—Computer Numerical Control. Computerized control of machines for manufacturing.

DISCUSSION—Common CNC machines include mills, lathes, grinders, and flame, laser, and water-jet cutters.

**IGES, *n***—Initial Graphics Exchange Specification, a platform neutral CAD data exchange format intended for exchange of product geometry and geometry annotation information; IGES version 5.3 was superseded by ISO 10303, STEP in 2006.

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.

**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.

**STEP, *n***—Standard for the Exchange of Product Model Data.

DISCUSSION—The common name for ISO 10303 that “provides a representation of product information, along with the necessary mechanisms and definitions to enable product data to be exchanged. [The standard] applies to the representation of product information, including components and assemblies; the exchange of product data, including storing, transferring, accessing, and archiving.”

**STL, *n***—*in additive manufacturing*, file format for 3D model data used by machines to build physical parts; STL is the de facto standard interface for additive manufacturing systems. STL originated from the term stereolithography.

DISCUSSION—The STL format, in binary and ASCII forms, uses triangular facets to approximate the shape of an object. The format lists the vertices, ordered by the right-hand rule, and unit normals of the triangles, and excludes CAD model attributes.

## 6. Keywords

6.1 additive manufacturing; rapid prototyping; 3D printing

## BIBLIOGRAPHY

(1) Wohlers Report 2011; <http://wohlersassociates.com>

(2) Castle Island; <http://www.additive3d.com>

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