**ISO/ASTM 52921:2013(E)**

# Standard Terminology for
# Additive Manufacturing—Coordinate Systems and Test Methodologies[1]

This standard is issued under the fixed designation ISO/ASTM 52921; 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 terminology includes terms, definitions of terms, descriptions of terms, nomenclature, and acronyms associated with coordinate systems and testing methodologies for additive manufacturing (AM) technologies in an effort to standardize terminology used by AM users, producers, researchers, educators, press/media, and others, particularly when reporting results from testing of parts made on AM systems. Terms included cover definitions for machines/systems and their coordinate systems plus the location and orientation of parts. It is intended, where possible, to be compliant with ISO 841 and to clarify the specific adaptation of those principles to additive manufacturing.

NOTE 1—The applicability of this standard to cladding has to be evaluated. Discussions are under progress.

NOTE 2—Non-cartesian systems are not covered by this standard.

1.2 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D638 Test Method for Tensile Properties of Plastics

E8/E8M Test Methods for Tension Testing of Metallic Materials

F2792 Terminology for Additive Manufacturing Technologies,

2.2 *ISO Standard:*[3]

ISO 841 Industrial Automation Systems and Integration—Numerical Control of Machines—Coordinate System and Motion Nomenclature

ISO 527 (all parts), Plastics — Determination of tensile properties

ISO 6892-1 Metallic materials — Tensile testing – Part 1: Method of test at room temperature

## 3. Significance and Use

3.1 Although many additive manufacturing systems are based heavily upon the principles of Computer Numerical Control (CNC), the coordinate systems and nomenclature specific to CNC are not sufficient to be applicable across the full spectrum of additive manufacturing equipment. This terminology expands upon the principles of ISO 841 and applies them specifically to additive manufacturing. Although this terminology is intended to complement ISO 841, if there should arise any conflict, this terminology shall have priority for additive manufacturing applications. For any issues not covered in this terminology, the principles in ISO 841 may be applied.

3.2 Furthermore, this terminology does not prescribe the use of any specific existing testing methodologies or standards that practitioners of AM may wish to employ for testing purposes; however, it is expected that practitioners will employ appropriate existing methodologies and standards to test parts made by AM.

## 4. Terminology

4.1 *Definitions*—Definitions shall be in accordance with Terminology F2792 and the following:

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[1] This terminology is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.01 on Test Methods, and is also under the jurisdiction of ISO/TC 261.

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[2] 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.

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

## Terms and Definitions—AM Machines and their Coordinate Systems

**build platform,** *n—of a machine,* any base which provides a surface upon which the build is started and supported throughout the build process (see A1.1).

> Discussion—The machine build platform may be solid or perforated and made from a wide variety of materials and constructions.

> 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 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— If the orientation of the material deposition or consolidation means, or both, is variable, it may be defined relative to the build surface (for example, a blown powder head may be kept normal to it. See also *Z* axis discussion).

**front,** *n—of a machine*, shall be designated by the machine builder.

> Discussion—Generally, this is the side of the machine that the operator faces to access the user interface or primary viewing window, or both. (See A1.1).

**machine coordinate system,** *n—*a three-dimensional Cartesian coordinate system as defined by a fixed point on the build platform "with the three principal axes labeled *X, Y,* and *Z* , with rotary axes about each of theses axes labeled *A, B,* and *C* , respectively" (see A1.1, A1.2, and A1.3) as stated in ISO 841.

**origin,** *n—*a designated reference point at which the three primary axes in a Cartesian coordinate system intersect. Synonyms: zero point, or (0, 0, 0) when using *X, Y,* and *Z* coordinates.

*build volume origin, n—*shall be located at the center of the build platform fixed on the build facing surface.

> Discussion—This is a universal origin reserved for the purpose of identifying the location of parts within the build volume. (See A1.1 and A1.2).

*machine origin, n—*origin as defined by the original equipment manufacturer. Synonyms: machine home, machine zero point.

**Z axis,** *n—of a machine*, for processes employing planar layerwise addition of material, shall run normal to the layers. (See A1.1 and A1.2.)

> Discussion—For processes employing planar layerwise addition of material, the positive *Z* shall be the direction from the first layer to the subsequent layers (see A1.1 and A1.2).

> Discussion—Where addition of material is possible from multiple directions (such as with blown powder systems), the *Z* axis may be identified according to the principles in ISO 841 (section 4.3.3) which addresses "swiveling or gimballing."

**X axis,** *n—of a machine*, shall run perpendicular to the *Z* axis and parallel to the front of the machine. (See A1.1 and A1.2.)

> Discussion—Where possible, the *X* axis shall be horizontal and parallel with one of the edges of the build platform.

> Discussion—The positive *X* direction shall be from left to right as viewed from the front of the machine while facing toward the build volume origin.

**Y axis,** *n—of a machine*, shall run perpendicular to the *Z* and *X* axes with positive direction defined to make a right hand set of coordinates as specified in ISO 841.

> Discussion—Where possible, the *Y* axis shall be horizontal and parallel with one of the edges of the build platform.

> Discussion—In the most common case of an upwards *Z* positive direction, the positive *Y* direction shall be from the front to the back of the machine as viewed from the front of the machine (see A1.1).

> Discussion—In the case of building in the downwards *Z* positive direction the positive *Y* direction shall be from the back of the machine to the front as viewed from the front of the machine (see A1.2).

## Terms and Definitions—Location and Orientation of Parts Within the Build Volume

**arbitrarily oriented minimum bounding box,** *n—of a part*, the minimum perimeter cuboid that can span the maximum extents of the points on the surface of a 3D part calculated without any constraints on the resulting orientation of the box (see A1.4 and A1.5).

> 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.

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

> Discussion—The center of the bounding box may lie outside the part.

**initial build orientation,** *n—of a part*, is the orientation of the part as first placed in the build volume and becomes the reference for any further part reorientation (see A1.6).

> Discussion—The initial build orientation is most easily communicated via 3D computer models (which can be interrogated for part position and orientation relative to the build volume origin). Where practical, the initial build orientation may be designated as the part orientation in the 3D computer model. Without electronic transfer of computer models, it should be documented with image(s) of the part(s) within the build volume and their orientation relative to the build volume origin (see A1.6 and A1.7).

**orthogonal orientation notation,** *n— of a part's initial build orientation*, may be used when the intended build orientation for a part is such that its arbitrarily oriented minimum

bounding box is aligned parallel to the *X*, *Y*, and *Z* axes of the build volume origin (as shown in A1.5(c)), its orientation may be described by listing which axis is parallel to the longest overall dimension of the bounding box first, followed by the axis which is parallel to the second longest overall dimension of the bounding box second, followed by the axis which is parallel to the third longest overall dimension of the bounding box.

DISCUSSION— For example, a specimen which is placed so that its longest dimension is parallel to the *Z* axis, the second longest dimension is parallel to the *X* axis, and its shortest overall dimension is parallel to the *Y* axis shall be defined as having a *ZXY* orientation (see A1.8 and A1.10 for examples).

DISCUSSION—Where symmetry allows unambiguous designation of orientation by listing fewer than three axes (in descending order of length), orthogonal orientation notation can be further abbreviated (see A1.9 and A1.10).

DISCUSSION—Some combinations of part symmetry in an orthogonal initial build orientation fully define only one possible orientation and therefore no image is required to communicate the initial build orientation. This is the case for parts like the dog bone specimen (D638 or ISO 527) in A1.10, which are bilaterally symmetrical (see A1.9) through its geometric center in the *XY*, *XZ*, *YZ* planes and have no rotational symmetry. This is also the case for parts like the round tension bar (see A1.10) which have 360° rotational symmetry through a center axis and are also bilaterally symmetrical across the plane bisecting the part perpendicular to the axis of rotational symmetry. Normally, an image is required to identify initial build orientation when parts have features with less than 360° rotational symmetry (see A1.7).

**part location,** *n*—within the build volume should be specified by the *X*, *Y*, and *Z* coordinates for the position of the geometric center of each part's arbitrarily oriented minimum bounding box with respect to the build volume origin (see A1.11 and A1.12).

DISCUSSION—Where finding the arbitrarily oriented minimum bounding box is not possible or practical, the coordinates of the center of the part's bounding box (aligned orthogonally to the build volume origin) when the part is in its initial build orientation may be used for defining part location.

**part reorientation,** *n*—the reorientation of parts within the build volume shall be specified by rotation around the geometric center of the part's arbitrarily oriented minimum bounding box in the sequence of *A*, *B*, and *C* (see A1.3 and A1.12) from a specified initial build orientation of that part.

DISCUSSION—Only non-zero angles need to be listed. For example, see A1.12 where the front row of parts are reoriented to *A*= 0, *B*= +45, *C*= 0 from an initial build orientation *Z* and are identified as *B*+45 from *Z*.

## 5. Keywords

5.1 additive manufacturing; test methods; machine coordinate system; part location; part orientation
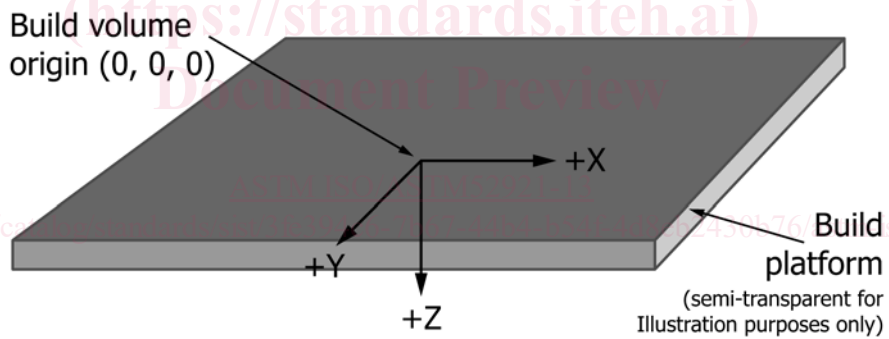
ANNEX

(Mandatory Information)

A1. IMAGES REFERRED TO IN THE DEFINITIONS

A1.1 See Fig. A1.1.
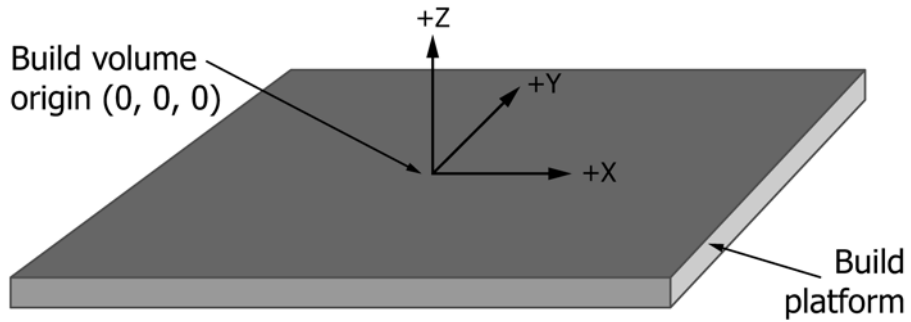
FIG. A1.1 Generic (Upward Building) Additive Manufacturing Machine/System

A1.2 See Fig. A1.2.

FIG. A1.2 Generic (Downward Building) Additive Manufacturing Machine/System
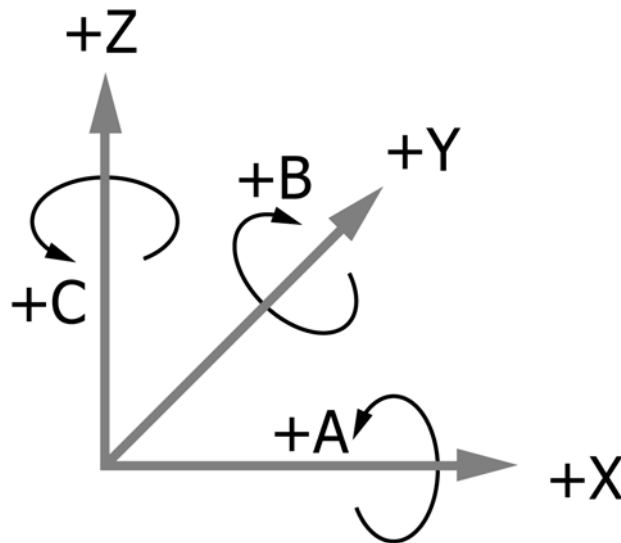
**A1.3** See Fig. A1.3.



**FIG. A1.3 Right Hand Rule for Positive Rotations with Reference to the Build Volume Origin**

**A1.3.1** As per ISO 841 when the thumb of the right hand points in the positive $X$, $Y$, or $Z$ directions, then positive rotation will be the direction from the hand to the finger tips.
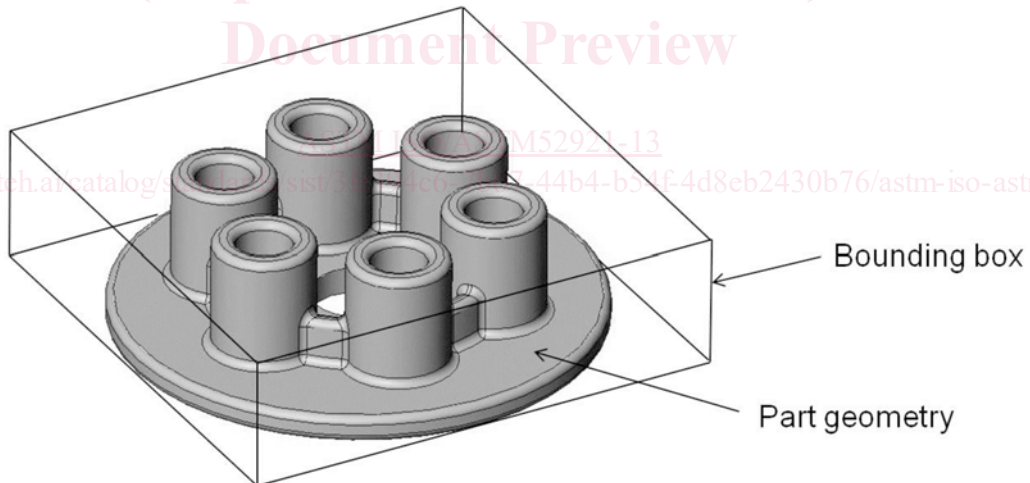
**A1.4** See Fig. A1.4.



**FIG. A1.4 Example of an Arbitrarily Oriented Minimum Bounding Box**

A1.5  See Fig. A1.5.

A1.5.1  Fig. A1.5 shows (*a*) a pressure plate in an arbitrary orientation and its bounding box aligned to the build volume origin, (*b*) the same geometry in the same orientation with its arbitrarily oriented minimum bounding box, and (*c*) the same part now re-oriented so that its minimum bounding box is parallel to the build volume origin.
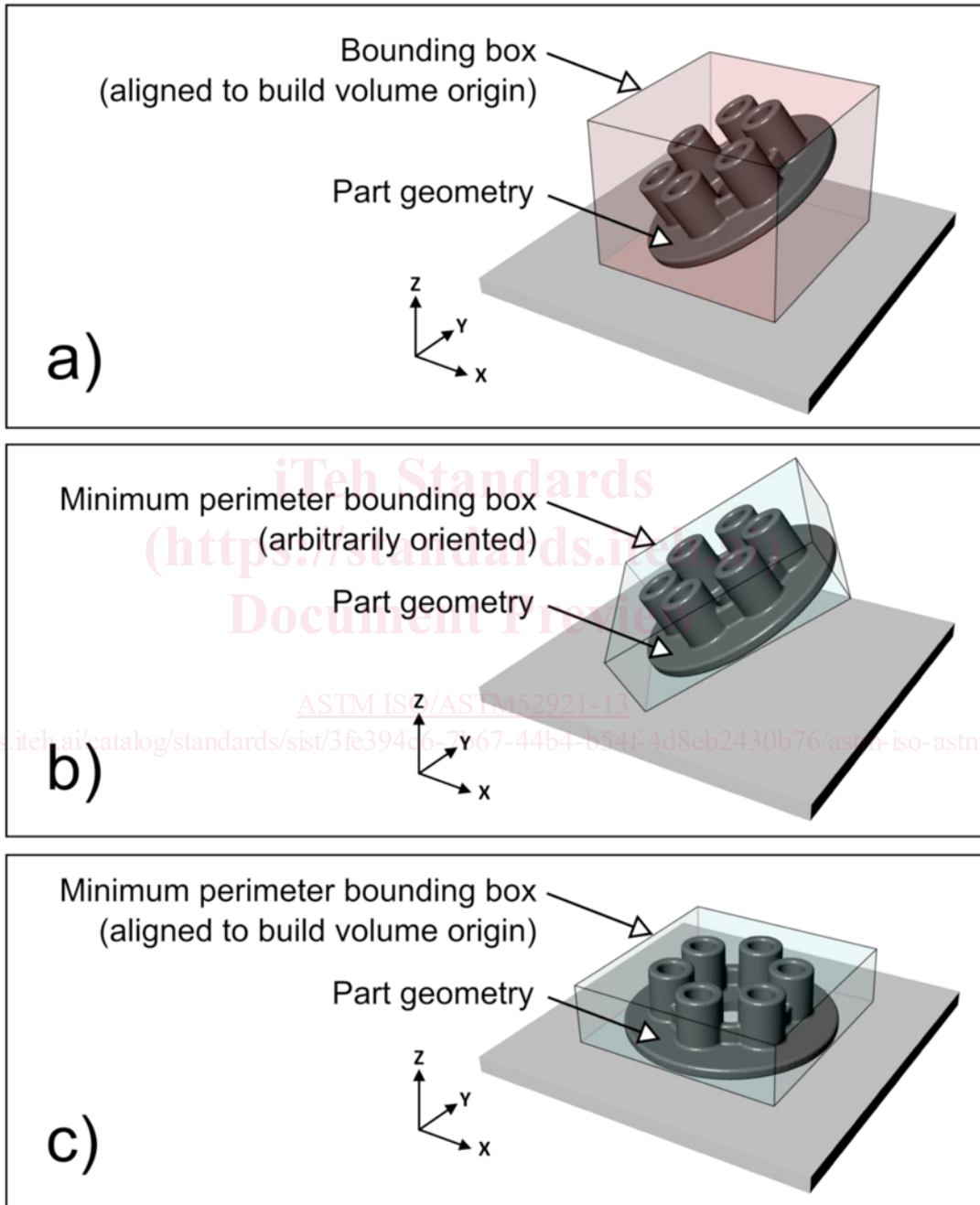


FIG. A1.5 Examples of Different Types of Bounding Boxes