USIBD Level of Accuracy (LOA) Specification Guide

Document C120™ **[Guide]** Version 2.0 - 2016

Guide for USIBD Document C220™**: Level of Accuracy (LOA) Specification for Building Documentation**

Purpose

The intent of Documents C120, C220 and C320 is to provide guidance to those individuals or organizations wishing to specify level of accuracy for professional building documentation services. In addition, these documents may be utilized by building documentation professionals when they are discussing a project with their client. Modifications may be made to suit an OWNER/STAKEHOLDER's specific requirements, if they are licensed to do so by the USIBD.

This Version 2.0 - 2016 Level of Accuracy (LOA) Specification is a reference or guideline that enables Professionals in the Architectural, Engineering, Construction, Owner (AECO) Industry to specify and articulate with clarity, the accuracy and means by which to represent and document existing conditions. The intent of the Specification is to provide a framework for the AECO industry to establish standards and consistency in building documentation so that those employing it will achieve the accuracy results they require.

Having a clearly defined LOA will assist Professionals in defining their documentation's intended use, and will allow downstream users to better understand the usability and the limitations of the documentation they are receiving.

The specification framework defines different levels of accuracy in terms of standard deviation for documenting existing building systems and sub-systems. Defining intent helps identify the acceptable methods and processes which can be used to achieve a prescribed LOA. In addition, when measurements are processed into some form of deliverable, such as line work or a model, it is also important to define the Level of Development (LOD) since the chosen means and methods of measurement may affect what outcome can be achieved within the LOD. While intent defines process, it is also important to recognize that various instruments and methods may be used, or may be used in combination, to achieve a given LOA. However, one should not infer that any particular instrument or method is or is not suitable for a given LOA.

Users of this Specification Guide are encouraged to study this document thoroughly prior to implementation of the associated LOA Specification. In addition to understanding how to utilize this document, it is very important to understand the fundamental concepts that affect accuracy prior to specifying accuracy. This document is not intended to teach these concepts. Instead, it is expected that any individuals who utilize this document already possess this knowledge.

USIBD Document Series

USIBD has published several different document series. In most cases there are three different documents packaged together:

- Guide: In any series the Guide will be numbered first and contains additional information helpful to using the documents.
- Template: The template (sometimes referred to as the Framework) is a blank document to modify for your use.
- Sample: An example of the template filled out for a theoretical or realized project.

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Acknowledgements

Thank you to all the individuals and organizations that reviewed and contributed to this document. Without your tireless efforts this document would not have been possible. This version of the LOA builds upon the previous version. Please refer to the previous version's acknowledgements for a list of those contributors. The below list of individuals directly contributed to the updates made in this version of the LOA.

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*We have followed the structure of **UniFormat**[TM] 2010 as published by CSI and Construction Specifications Canada (CSC). For a more in-depth explanation of **UniFormat**[TM] and its use in the construction industry visit http://www.csinet.org or contact CSI, 110 South Union Street, Suite 100, Alexandria, VA 22314. (800) 689-2900*

The U.S. Institute of Building Documentation Level of Accuracy (LOA) Specification Guide

The Guide

This Guide and the associated Sample Document are provided solely for the information and convenience of USIBD Document users. It is one of many resources available to the AECO Industry involved in building documentation and is not intended to be the sole resource in determining LOA. The Guide assumes that the USIBD Document users are experienced in building documentation and will use professional judgment in implementing suggested guidelines contained herein.

Level of Accuracy (LOA) Specification Introduction

Overview

Level of accuracy specifications are something that the AECO industry has long struggled with in regard to existing conditions building documentation. What is meant by accuracy? Is accuracy relative or absolute? Is accuracy related to the ultimate intent for the project? Understanding these basic concepts at the start of a project may help avoid problems in as-built deliverables.

A common practice in the design industry is to represent 2D or 3D building data in an orthogonal fashion. Real world existing conditions are seldom orthogonal. The challenge then becomes how does one represent the real world out-of-plumb conditions? Are they to be represented orthogonally or with respect to their true out-of-plumb conditions? To complicate matters further, many of today's design software packages prefer to work in an orthogonal fashion and are limited in their ability to accurately represent out-of-plumb conditions. When real world out-of-plumb conditions are represented in an orthogonal fashion, error is introduced. How is this error then reconciled with the specific level of accuracy demanded by a project?

In addition, when documenting existing conditions, it is common to encounter hidden or concealed conditions, making it difficult or even impossible to document certain Levels of Development and/or achieve certain Levels of Accuracy. When these conditions occur, are the expectations of the AECO team consistent with what can actually be achieved with regard to meeting the required accuracies. Also, it is important to recognize that the level of accuracy acquired through data capture may be different than the level of accuracy after the captured data is processed. These are important considerations when specifying a Level of Accuracy.

Background

Relevant Standards

While there may be other existing guidelines and standards that prescribe a level of accuracy schema, there appears to be a lack of a commonly recognized standard that has been accepted by the AECO industry with regard to building documentation. Our approach in developing the LOA Specification was to identify existing recognized LOA specifications and use those as a model from which to base ours. One such specification is the DIN 18710 standard which is widely recognized and accepted in Europe. The DIN 18710 specification prescribes five levels of accuracy in terms of standard deviation, each with a specified range. The upper and lower range values of this specification seem suitable for the application of building documentation. However, the specification as written does not recognize or distinguish how the specified standard deviations relate to building systems and sub-systems.

To address this we turn to the Level of Development (LOD) Specification developed by the AGC's BIM Forum which is based on the AIA's G202-2013 Building Information Modeling Protocol Form and is organized by CSI *UniFormat*™ 2010. The initial AIA LOD specification has already received general acceptance by the AECO industry. The BIM Forum's LOD document is expected to receive similar acceptance.

Given the acceptance of these other standards, the logic on which the framework for these standards is based, and the USIBD's support of interoperability, we believe the USIBD's LOA Specification should follow suit with a similar framework that further integrates these known standards in a meaningful way to satisfy the AECO Industry's need for an LOA Specification that can be used to prescribe accuracy on building documentation projects.

Levels of Accuracy

Fundamental LOA Definitions

The USIBD's LOA is structured in five increments of ten beginning with LOA10 and extending thru LOA50. This two digit "Ten" series is intended to differentiate itself from the BIM Forum's LOD three digit "one hundred" series thus avoiding potential confusion. The system uses a similar and familiar structure in the same sense that it has levels which begin low at LOA10 and progress to high at LOA50. The five defined Levels of Accuracy are – LOA10, LOA20, LOA30, LOA40 and LOA50.

LOA10 >>> LOA 20 >>> LOA 30 >>> LOA40 >>> LOA50

Low   **>>>**   **High**

This specification prescribes five levels of accuracy for building documentation. Each of the five levels can be applied within the same project as the Level of Accuracy may be applied to the elements of the building documentation project and not necessarily to the project in totality. This system is designed for the AECO Industry to achieve a well-defined, cost-effective scope for the project.

Level	Upper Range	Lower Range
LOA10	User defined	5cm *
LOA20	5cm *	15mm *
LOA30	15mm *	5mm *
LOA40	5mm *	1mm *
LOA50	1mm *	0 *

Specified at the 95 percent confidence level.

The documentation methods used by Professionals vary with project goals and equipment available. Also, documentation technology is constantly changing; therefore, a standard for a particular LOA cannot specify methods or equipment lest it become obsolete even before it is adopted. The framework is a general description of the project requirements along with reporting and accuracy requirements. This framework will aid in (1) defining project goals and elements to be documented, (2) determining how the results are to be reported, (3) establishing the level of accuracy of the results, and (4) formulating the method of validation. Appropriate procedures and equipment should be selected to obtain the accuracy required as defined in the LOA. In other words, a well-defined execution plan is key to obtaining the required LOA.

The Documentation Professional must check their work to assure that the intended accuracy is being achieved. Relative Positional Accuracy does not pertain to the location of a particular point or corner in the world but to the accuracy of the measurements used in the documentation process. Therefore a good test of the relative positional accuracy is to take check measurements of some of the distances in the field. The Documentation Professional should check his or her fieldwork by making redundant measurements whenever possible. This is not a new concept. This does not mean that every element must have a series of detailed checks; however, redundancy has always been one of the best ways to make sure that the fieldwork has met the quality that was expected.

The DIN 18710 Standard

The DIN 18710 Standard is based on a metric unit of measure. The USIBD LOA levels are also based on a metric unit of measure. However, the USIBD's LOA provides an imperial unit conversion. It should be noted that this conversion is not an exact translation from metric to imperial units. When translating to imperial units we elected to round to the nearest 1/16th of an inch. Rounding to fractional equivalents of less than 1/16th of an inch was viewed as impractical when applied to commonly used means and methods of building construction and documentation. Any user of the USIBD LOA specification that requires translation from one unit of measure to the other will need to make their own decisions on how to account for this rounding in their conversion.

The upper range of LOA10 has been intentionally left undefined. Instead, we have set the lower range at [5cm] and [2in]. The upper range of LOA10 may be defined by the specifier to meet their own requirements, or by leaving it undefined, the specification is requiring that the lower range of LOA10 must be achieved.

It is important to note that while each LOA is defined by a range of accuracy, any LOA higher than that which is specified is presumed also to be acceptable since it exceeds the requirements of the specified LOA.

Numbers represented in the following table relate to standard deviation of 2 Sigma.

Level of Accuracy (2 σ std dev)					
-	5cm	15mm	5mm	1mm	Upper Range (Metric)
5cm	15mm	5mm	1mm	0	Lower Range(Metric)
LOA10	LOA20	LOA30	LOA40	LOA50	

Measured Accuracy vs. Represented Accuracy

The LOA framework is further structured into two parts. The first part is referred to as Measured Accuracy and the second part is referred to as Represented Accuracy.

$	Measured Accuracy	$$$$$				$	Represented Accuracy	$$$$$		
X	Absolute	If Absolute - describe reference frame here				X	Absolute	If Absolute - describe reference frame here		
	Relative	If Relative - describe measure of relativity here					Relative	If Relative - describe measure of relativity here		
Level of Accuracy (2 σ std dev)						Level of Accuracy (2 σ std dev)				
-	5cm	15mm	5mm	1mm	Upper Range (Metric)	-	5cm	15mm	5mm	1mm	Upper Range (Metric)
5cm	15mm	5mm	1mm	0	Lower Range(Metric)	5cm	15mm	5mm	1mm	0	Lower Range(Metric)
LOA10 LOA20 LOA30 LOA40 LOA50				(A, B, or C) Validation	Note	LOA10 LOA20 LOA30 LOA40 LOA50				(A, B, or C) Validation	Note

Measured Accuracy represents the standard deviation range that is to be achieved from the final measurements taken regardless of the method used to acquire those measurements. Represented Accuracy represents the standard deviation range that is to be achieved once the measured data is processed into some other form such as line work or a model. When specifying Measured Accuracy, the specifier must choose whether the specified accuracy in terms of standard deviation shall be absolute or relative [See T&D for further clarification].
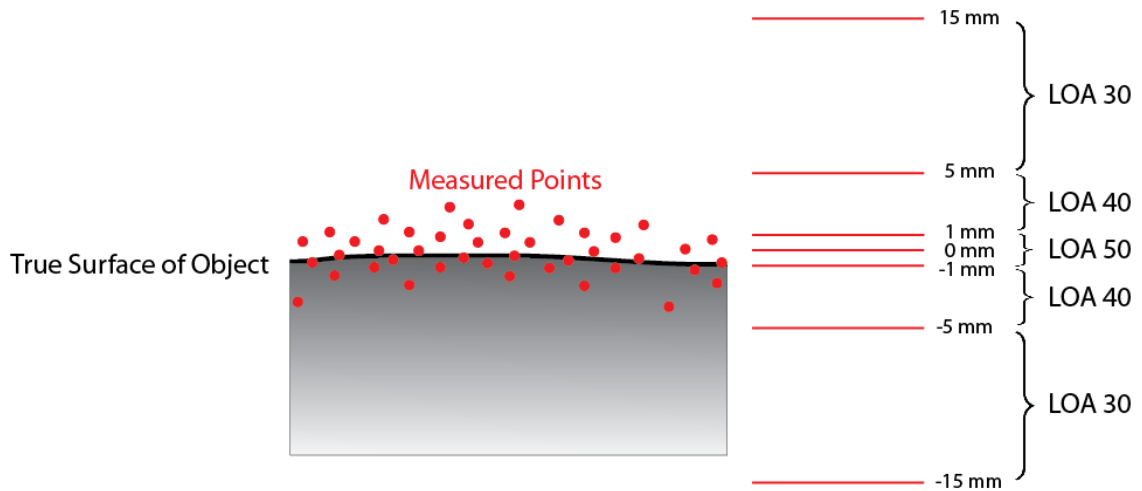
Sometimes, only measurements are required. In such cases, the Measured Accuracy will be specified, but the Represented Accuracy will not. When measurements are to be taken and processed into some other deliverable, then both a Measured Accuracy and a Represented Accuracy should be specified. In some instances, a specifier may only be concerned about the Represented Accuracy. The specifier may choose not to specify a Measured Accuracy and let the building documentation professional determine the Measured Accuracy LOA required to achieve the specified Represented Accuracy. [See T&D for a conversion example from often used tolerance measures to standard deviations.]
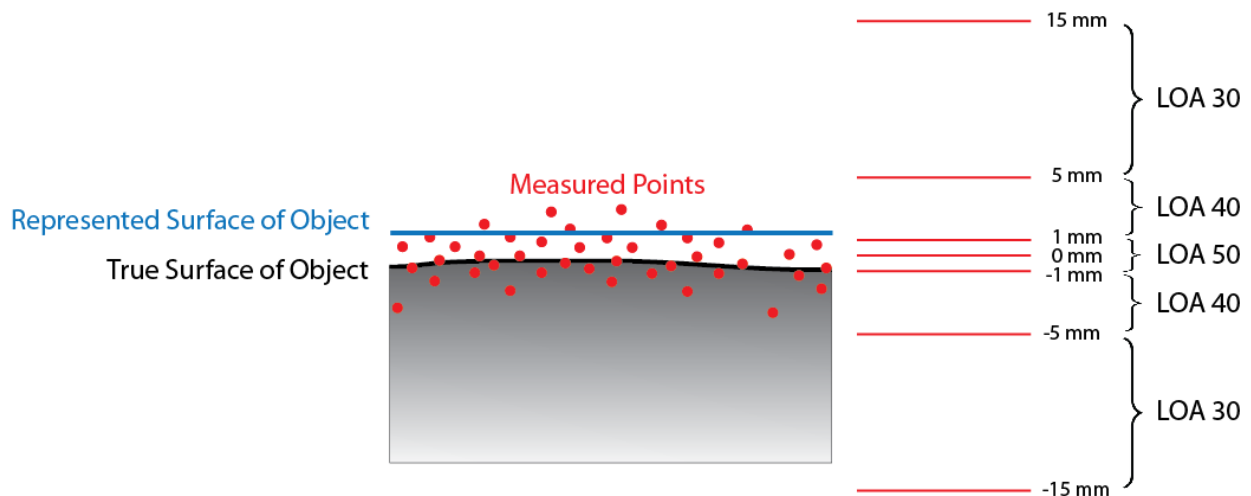
The primary distinction is that error will always be introduced when measured data is processed into, or 'represented' as, some other form of deliverable. This being the case, it is important to specify the Level of Accuracy associated with each independent of the other.

UniFormat™

As previously mentioned, we have elected to base the LOA framework on the CSI *UniFormat*™ standard. *UniFormat*™ is a standard for classifying building specifications, cost estimating, and cost analysis. *UniFormat*™ classifies elements as major components common to most buildings. It was developed through an industry and government consensus and has been widely accepted as an ASTM standard. For the purpose of this version of the LOA Specification, we are providing suggested LOA's for *UniFormat*™ categories A through G for Measured Accuracy only. In this version of the LOA specification we have elected to include *UniFormat*™ Levels 1 thru 3. Level 4 may be added in a future release of the LOA specification.

UniFormat™ Categories

A - Substructure

B - Shell

C – Interiors

D – Services

E – Equipment & Furnishings

F – Special Construction & Demolition

G – Building Sitework

The *UniFormat*™ levels allow a specifier to easily expand or contract the amount detail they wish to specify. For example, a small project may only require a very simple LOA Specification. In this case the specifier may choose to not to expand the framework beyond Level 1. More complicated or challenging projects can expand to Levels 2 or 3 to reveal more detailed building systems. It is important to note that if a LOA is not required for a given building subsystem, the specifier may simply choose not to specify one and leave the LOA box unchecked.

Field of application: ◉ Standard ○ Heritage
Dimensional units: ○ Imperial ◉ Metric

$	Measured Accuracy	$$$$$
X	Absolute	If Absolute - des
	Relative	If Relative - desc

Level of Accuracy (2 σ std dev)

	-	5cm	15mm	5mm	1mm
	5cm	15mm	5mm	1mm	0

CSI UniFormat™ 2010	LOA10	LOA20	LOA30	LOA40	LOA50
19 A SUBSTRUCTURE		x			
29 B SHELL		x			
48 C INTERIORS		x			

Levels can be expanded to reveal building sub-systems of the primary *UniForm*™ category. The example below has been expanded to reveal Level 2.

Field of application: ◉ Standard ○ Heritage
Dimensional units: ○ Imperial ◉ Metric

$	Measured Accuracy	$$$$$
X	Absolute	If Absolute - des
	Relative	If Relative - desc

Level of Accuracy (2 σ std dev)

	-	5cm	15mm	5mm	1mm
	5cm	15mm	5mm	1mm	0

CSI UniFormat™ 2010	LOA10	LOA20	LOA30	LOA40	LOA50
19 A SUBSTRUCTURE					
20 A10 Foundations		x			
23 A20 Subgrade Enclosures		x			
25 A40 Slabs-on-Grade		x			
28					
29 B SHELL					
30 B10 Superstructure		x			
34 B20 Exterior Vertical Enclosures		x			
41 B30 Exterior Horizontal Enclosures		x			
47					
48 C INTERIORS					
49 C10 Interior Construction		x			
57 C20 Interior Finishes		x			

Or, if the project demands, it can be expanded an additional level (Level 3) to reveal and specify even greater detail:

Level 1	Level 2	Level 3	CSI UniFormat™ 2010	LOA10	LOA20	LOA30	LOA40	LOA50
A			SUBSTRUCTURE					
	A10		Foundations					
		A1010	Standard Foundations			x		
		A1020	Special Foundations			x		
	A20		Subgrade Enclosures					
		A2010	Walls for Subgrade Enclosures			x		
	A40		Slabs-on-Grade					
		A4010	Standard Slabs on Grade			x		
		A4020	Structural Slabs on Grade			x		
B			SHELL					
	B10		Superstructure					
		B1010	Floor Construction				x	
		B1020	Roof Construction			x		
		B1080	Stairs				x	

Measured Accuracy: $ ... $$$$$
X — Absolute — If Absolute - des...
— Relative — If Relative - desc...

Level of Accuracy (2 σ std dev)

-	5cm	15mm	5mm	1mm
5cm	15mm	5mm	1mm	0
LOA10	LOA20	LOA30	LOA40	LOA50

Suggested LOAs

The LOA Framework is intended to be flexible enough to work on both small and large projects. It has also been designed to assist the specifier by offering suggestions for more commonly utilized LOAs. At the center of the following bell curve, we see the widest application for a given LOA being represented as "Suggested." However, in some instances it may be desirable to specify an LOA outside of this range for applications that are less common, but that are not considered extreme. We term these applications as "Accepted." Finally, we refer to the most extreme instances of an LOA tolerance as "Special." These are LOAs that are considered special cases and may exceed most commonly-specified applications.

LEGEND

- Suggested (Most commonly utilized)
- Accepted (Commonly utilized)
- Special (Special case - may exceed most applications)

Distribution of Accuracy Levels

Once the specifier determines the appropriate level of building subsystem to reveal in the LOA Framework, they can then specify a desired LOA by simply putting an "**X**" in the corresponding box. To help the specifier narrow down their decisions, we have identified selections as either "Suggested", "Accepted", or "Special."

These 'Suggested' selections are based on the most common building documentation applications. Specialized applications, such as heritage documentation, plant documentation, etc., may require LOAs other than what are suggested in the Standard LOA Framework.

Bright yellow boxes are "Suggested" LOAs. In some cases there may be more than one "Suggested" LOA. This may occur more commonly if the Framework is reduced to show less detail. Suggested LOAs are based on generally-accepted standard deviations and/or standard deviations that are defined in recognized industry standards. [See T&D for a conversion example from often used tolerance measures to standard deviations.] It is important to note, however, that the specifier must do their own evaluation of whether these "Suggested" LOAs are appropriate for their project.

"Accepted" LOAs are identified by a white box. These LOAs are generally viewed as having an accuracy that is outside the most commonly-utilized range in the industry for the respective building system or subsystem. However, depending on the application, this accuracy may be deemed appropriate in a given situation or, if on the lower side, as a cost-saving measure.

Grey boxes marked as "Special" are generally viewed as having a standard deviation that is higher than accepted in the industry for the respective building system or sub-system. These boxes typically would not be checked in a normal application of this specification. However, it should be noted that the ultimate determination of whether to disregard this lies with the specifier. Should the specifier determine that a unique requirement exists, they can still specify an LOA that occurs in a grey box.

Standard Framework vs. Heritage Framework

There are two options for viewing Suggested LOA's within the LOA Framework Template. The first is the "Standard" Framework which is intended for most common building documentation applications through all phases of the facility lifecycle. The second is the "Heritage" Framework which is intended for use on heritage applications that, generally speaking, have higher LOA requirements.

For the convenience of the user, a radio button has been provided within the same template which allows the user the ability to easily switch between both of these options.

Suggested LOA shading for Standard applications

Suggested LOA shading for Heritage applications

Generally speaking, specifying a higher LOA is expected to result in higher costs for the documentation.

By providing "Suggested" LOAs, we are hoping to offer the specifier a tool that can be used to make prudent, yet quick decisions when preparing their specification. However, it is ultimately up to the specifier to determine which LOA is appropriate for each building system/subsystem in their project.

Means and Methods of Measuring

There are various means and methods for acquiring measurements as well as numerous instruments that can be used for taking measurements. [See T&D for calibration advice.] This specification is means and methods agnostic. It is intended to be used with any suitable means and methods of acquiring and representing building measurements.

Whether the method of measuring is with a steel tape measure, a total station, a laser scanner, photogrammetry, pacing-off, etc., it should not be assumed that any one particular instrument is being used in conjunction with this specification framework. Likewise, no particular measurement instrument or method should be thought to be precluded from being used with this specification.

Some methods may utilize survey control while other methods may utilize simple control techniques. The decision of which means and methods shall be used to achieve a specified LOA should remain with the building documentation professional. This specification only prescribes the LOA that is to be achieved and does not prescribe how to achieve it.

How to Specify LOA for your Project

The LOA Specification also gives the specifier the ability to specify a method of validation for both the measured accuracy (standard deviation) and the represented accuracy (standard deviation). [See T&D to differentiate between accuracy and resolution.]

LOA Validation

Measurement Validation

The LOA Specification provides three choices for measurement validation:

  A. No data check
  B. Check by overlapping data sets
  C. Check by independent measurements or methods

Representation Validation

The LOA Specification provides three choices for representation validation:

  A. No check
  B. Double check
  C. Triple check

LOA Schema

Measured Accuracy	Validation	Relative (rel) Absolute (abs)		Represented Accuracy	Validation		Relative (rel) Absolute (abs)
YY	A	rel	-	ZZ	A	-	rel

YY	:	30	Measurement accuracy (standard deviation) of 5 to 15mm
A	:	B	Check by overlapping data sets
rel	:	rel	Relative accuracy (standard deviation) in regards to a reference system
ZZ	:	20	Representation accuracy (standard deviation) of 15 to 50mm
A	:	A	No check of the final representation
rel	:	rel	Relative accuracy (standard deviation) in regards to a reference system

Specified LOA reads as follows:

30Brel-20Arel or, as spoken; thirty B relative twenty A relative

Note: if the specifier is only specifying one component of the LOA (i.e., measured data only: registered scan data is the only deliverable), they would simply insert an 'X' for the missing LOA. The previous LOA would read as follows:

30Brel-X or, as spoken; thirty B relative X

Note: if the specifier is only specifying the represented data (i.e., a model is the only deliverable), they would simply insert an 'X' for the missing LOA. The previous LOA would read as follows:

X-20Arel or, as spoken; X twenty A relative

The method of validation is specified after the LOA in the specification framework.

Notes

1. With regard to the LOD Specification, any given LOA may apply to any given LOD.
2. There is no correspondence between LOA's and design phases.
3. There is no such thing as an "LOA XX model." Buildings contain elements and assemblies of various materials with unique properties, thus the standard deviations or manufacturing tolerances of each will vary. For example: concrete as a building material cannot be controlled to the same degree as a material such as steel, thus the respective LOAs are expected to vary.
4. Clarification regarding degrees of confidence with respect to the LOA definitions and the accuracy (standard deviation) of existing record drawings will be addressed in a future version of the LOA Specification.
5. Clarification regarding reconciling orthogonal and real-world, out-of-plumb conditions will be addressed in a future version of the LOA Specification.
6. Methodologies for validating accuracy will be addressed in a future version of the LOA Specification.
7. Suggested LOA's for Represented Accuracies may be addressed in a future version of the LOA Specification.

Terms and Definitions

Absolute Accuracy

Refer to *"Accuracy"*

Accuracy:

Also refer to *"Precision and Correctness"*

Absolute Accuracy

A standard deviation related to a given reference frame (e.g., a building) or state coordinate system. A given absolute accuracy usually means a global standard deviation over the whole object, floor or building. Of course, there can be different levels of accuracy for position and height component for the same object.

Absolute accuracies are usually independent of distance or the number of setups.

Measured Accuracy

A standard deviation that relates to the measured data. The measured accuracy is mostly affected by the standard deviation of the sensor, the way measurements are being joined into a common coordinate system and - for reflectorless measuring devices – by the object itself in terms of angle of incidence, surface reflectivity, color and roughness.

The measured accuracy can be stated as absolute or relative, depending on the project requirements or the deliverables.

Relative Accuracy

A standard deviation related not to a fixed superior datum, but within an object's region (e.g., from front to back door) or within one or more setups. A relative standard deviation is mostly used when higher demands arise for special parts of a building knowing that the accuracy dilutes over distance by concatenation of multiple setups.

For example, the clearance of a door might be acquired with a higher accuracy (better standard deviation) than the door's position inside the building itself. In this case, the data acquisition from a single measurement or setup should be carried out with higher accuracy than the referencing between multiple setups.

Especially when using mobile data acquisition devices (e.g., mobile or portable scanning systems), the relative accuracy in terms of standard deviation within a limited area is much higher than the absolute accuracy in a given reference system.

Represented Accuracy

Unlike measured accuracy the represented accuracy is independent of the sensor or object specific parameters. The represented accuracy is related to the way measured data is being transformed into the final deliverable and describes how well the deliverable matches the acquired data.

The represented accuracy can only be even or less accurate than the measured accuracy, since data processing is usually based on measurement. It has to be taken into account that resolution can greatly affect the represented accuracy if too few measurements are being taken.

It also has to be stated whether represented accuracy is meant to be absolute or relative. Absolute accuracies in regards to a superior coordinate system are sometimes given as a tolerance value (see accuracy vs. tolerance), especially for steelworks. Mostly the represented accuracy is defined as a relative measure in order to match the local shape of an object.

Calibration

Mathematic reduction of systematic deviations through comparison against precise reference values. Usually the calibration of measurement tools is being done by the manufacturer, but there are also some field calibration procedures that can be done by the end user.

Confidence (Definition per NSPS – National Society of Professional Surveyors)

Most standards in use today are specified at the 95 percent confidence level. This means that if we have a measured distance of 1000 feet with stated reliability of plus or minus 0.10 feet at 95 percent confidence level, we can be confident that a measurement of that line will be between 999.90 feet and 1000.10 feet 95 out of 100 times.

As an example, a Surveyor establishes two corners by a radial survey. The distance between the corners is computed and shown on the plat. As a check, the Surveyor measures directly between the corners, not once, but 100 times. The measurements are made on different days and under different conditions. If all corrections for systematic error are made, the average of those measurements probably approaches the correct length of that line and the standard deviation of those measurements is a good measurement of the accuracy of that distance. If the value of the standard deviation is 0.05 feet, then we would say that the line length is equal to the average distance, plus or minus 0.05 feet at the 68 percent confidence level. In other words, of the 100 measurements, there could have been 32 measurements that differed by more than 0.05 feet from the average. At the 95 percent confidence level, we can expect that there will be 5 measurements that are 2 times 0.05 feet or 0.10 feet more or less than the average distance.

As a practical matter a Surveyor does not measure a line 100 times. The Surveyor makes one high quality check measurement. The Surveyor makes the assumption that this check measurement is the correct value. The difference between the correct distance and the calculated distance is assumed to be an approximation of the standard deviation. The 95 percent confidence interval value will be 2 times the approximate standard deviation. This double value is the value that is compared in the NSPS (National Society of Professional Surveyors) Standard. It must be pointed out again that the check measurements should be a very reliable measurement based on a specification that will provide accuracy above those being checked. For many years, experienced surveyors have recognized a value that they considered an acceptable variation for their measurements in the field. This value is similar to the standard deviation, or a value at the 68 percent confidence level. Therefore, this value is one-half of the value at the 95 percent confidence level that is used in the NSPS Standards. In other words, if the Surveyor's normally acceptable variation is 0.05 feet, that really is 0.10 feet at the 95 percent confidence level.

Control:

"Control," in the context of Building Survey, is the reference to a fixed network of measured points at a higher order of accuracy which underlay a series of more detailed measurements. There are various methods of control that may be used, each often chosen based on project specific factors such as: survey type, scale, cost, required accuracy, and speed of data acquisition.

Simple Control

Simple Control is a term used to define a series of higher order measurements relying on triangulation and/or carefully chosen elements which are used for the basis to control more detailed measurements.

Survey Control

Survey Control is used for the same purpose as Simple Control, but is often more accurate and mostly intended for longer term use. Survey Control is typically set with the use of instruments such as Total Station Lasers. For example Survey Control can utilize permanently installed points on the ground, tripods with reflectors, or reflective tape on building walls, etc.

Coordinate System

A coordinate system defines a common frame for a single measurement or a group of measurements. It is commonly defined as two or three dimensional. In most cases the coordinates are given in three dimensions as X, Y, Z values in Cartesian notation. When using handheld laser range finders and total stations the coordinate system can also be based on spherical coordinates like horizontal and vertical angle plus distance.

For larger objects multiple coordinate systems (e.g. one for each setup of a laser scanner or total station) have to be transformed into a common, or even global coordinate system. Coordinate systems can be local, dependent on objects, or on control point networks.

Most commonly, coordinate systems are defined as right handed systems with axis definitions like X pointing to the east, Y pointing to the north, and Z for height.

Correctness

Refer to *"Precision and Correctness"*

Datum

A datum is a coordinate system that is defined by a set of reference points. In other words assigning numbers to at least three points in a coordinate system that are not aligned on a straight line can define a datum. Defining a 2D datum requires at least two reference points; for a 3D datum three points are needed.

For example: setting the origin of a coordinate system to the intersecting point of a building's edge and the surrounding surface; a second point along the wall as lying on the X-axis, and a third point up the edge as lying on the Z-axis gives a datum for measuring this building. Of course all datum points may be chosen freely depending on their accessibility.

Measured Accuracy

Refer to *"Accuracy"*
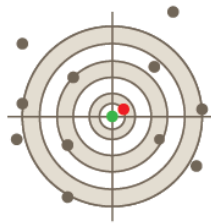
A
Precision: Bad
Correctness: Good
Accuracy: Medium
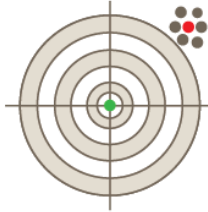
B
Precision: Good
Correctness: Bad
Accuracy: Bad
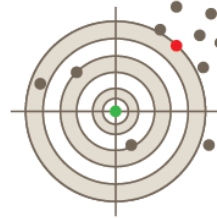
C
Precision: Bad
Correctness: Bad
Accuracy: Bad

D
Precision: Good
Correctness: Good
Accuracy: Good

LEGEND
- True Value
- Mean of the Individual Values
- Individual Values

From a geodetic point of view an accuracy measure is supposed to consist of two elements: precision and correctness.

Precision

The precision component describes the bandwidth of repeated statistically-independent measurements under identical conditions and is mainly defined by the random deviations (e.g., measurement noise) of a sensor.

Correctness

In contrast to the precision component, the correctness of a measurement is mostly influenced by systematic deviations (e.g., due to mis-calibrated equipment, bad angles of incidence or effects resulting from the object's surface).

Good accuracy values can only be obtained if both the precision and the correctness components have little, if any, influence.

The accuracy, therefore, consists of both precision and correctness and describes the accordance of a measurements result in regards to the true value.

Relation between tolerance and standard deviation

When working with mechanical or civil engineers is it necessary to translate between often used tolerances and accuracies in terms of standard deviations. With a given overall tolerance the required standard deviation is a function of

  a) P: Proportion of measurement tolerance T_M in regards to overall tolerance T
  b) R: Level of confidence (statistical parameter)

With a commonly used value of P = 30% the portion of the measurement tolerance can be obtained by

$$T_M = T\sqrt{1 - (1 - P)^2}\ .$$

In order to derive the necessary standard deviation $\sigma_{x,y,z}$, first the confidence level 1-α has to be defined, where a value of e.g. 1-α = 95% is frequently used. Of course, this value has to be regarded in the project-specific context and can also be higher or lower.

By choosing a confidence level of 95% the standard deviation is defined by

$$\sigma_{x,y,z} = \frac{T_M}{2k} = \frac{T_M}{3,92}.$$

As a rule of thumb the standard deviation has to be roughly 1/5th of the overall tolerance for P = 30% and 1-α = 95% in order to match the manufacturing requirements.

Relative Accuracy

Refer to *"Accuracy"*

Repeatability

Repeatability is a statistical measure that gives information about the relations between one or more repeated measurements. In terms of standard deviations, this measure is a repeatable standard deviation.

Represented Accuracy

Refer to *"Accuracy"*

Resolution

Absolute value for the distance of two independently acquired single measurements at the object's surface. In the case of laser scanning, the resolution is equivalent to the grid spacing at the object's surface.

Resolution versus Accuracy

On non-linear surfaces, the accuracy of a measured object's surface is determined by a couple of parameters. One of them is the point resolution, which needs to be raised up to a certain level where the surface structure of interest is being fully acquired.
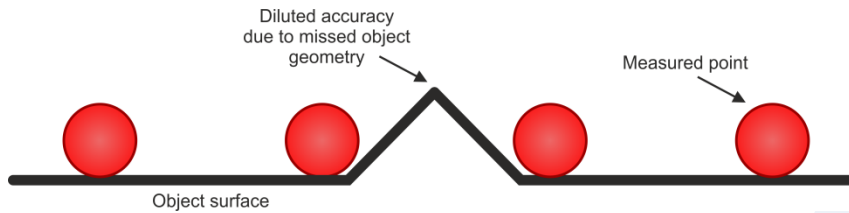
For contactless measurements like laser scanners and total stations, this level depends on the object distance and the beam diameter at the object's surface. It has to be taken into account that increasing the point distance to a value smaller than the spot diameter only results in more data and not in any gain of information.

Computing adjusted (building) models out of an oversampled dataset like shown below (too high point resolution) will give erroneously optimistic estimations for the resulting standard deviation due to unconsidered correlations. So oversampling a dataset by too high point resolutions has to be avoided.
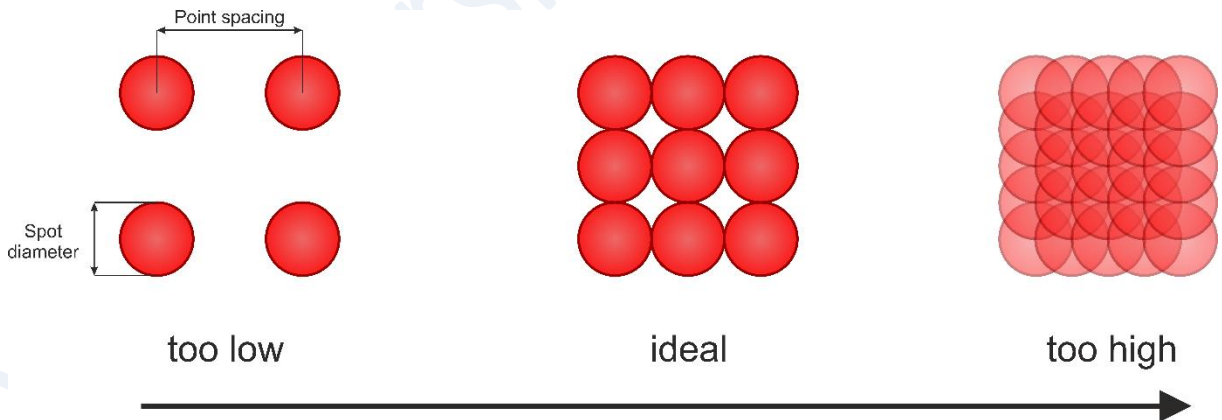
Standard Deviation

The standard deviation is a measure in order to express the variation of an unknown parameter. For example: a distance measurement or a 3D-coordinate. Standard deviations are used to take into account that the result of a repeated measurement will vary each time being carried out. Mathematically spoken the standard deviation is the square root of a parameter's variance.

When comparing standard deviations of multiple sensors like different laser scanners, or a handheld laser range finder versus a total station the confidence level has to taken into account as well. A standard deviation is usually used to express the "margin of error" or the confidence level of a measured variable by multiplying its value with integers like 1, 2 or 3 (called sigma values), or giving percentage values for the confidence level of that standard deviation.

For example defining a standard deviation of 5 mm with a confidence level of 2 sigma, or 95% means that 95% of all measurements have to be within a range of 5 mm accuracy. If the one sigma range is required, only 67% of all measurements have to be in the 5 mm range. A standard deviation without defining the respective confidence level is incomplete.

The LOA always uses the 2 sigma range (95% confidence level) which can be considered the standard in surveying.

Tolerance

In contrast to standard deviations, tolerance values do not "allow" statistically varying parameters. If a window has to be assembled into a window's opening, it doesn't help to know that it will fit in 95% of all cases, since a 100% rate is required.

Tolerances do allow a variation of values, eg. by defining a tolerance as 2 m ± 5 mm, but in theory this deviation must not be exceeded in any case which means it requires a confidence level of 100%.

Since measuring sensors do have varying measurements, the sensor of choice has to be accurate enough in order to meet the tolerance requirements. For computing the required sensor accuracy with a given tolerance please refer to section "relation between tolerance and standard deviation". In construction, a rule of thumb is that the sensor has to have a standard deviation of 1/5th of the given tolerance. In machine construction this relation frequently goes up to 1/10th of the tolerance value.

In our example this means that an object with a tolerance requirement of 2 m ± 5 mm would roughly require a handheld laser range finder, a laser scanner, or a total station that has a specified standard deviation of 1 mm (2 sigma or 95% confidence) or a standard deviation of 0,5 mm (1 sigma or 67% confidence).

It of course has to be taken into account that angular and distance values mostly have different standard deviations, and therefore, can meet different tolerance requirements depending on if the distance or the angular value mostly contributes to the measured parameter (eg. width of window opening).

LOA Document Series Revision History

While this document is intended to be used solely as a reference tool, , it should be recognized that the means and methods of building documentation are continuously evolving. As such, this document will be updated periodically. Any officially-recognized updates will be listed in the revision history below. Users of this Specification Guide are ultimately responsible for its application to their specific needs.

C120 Guide Versioning:

Version	Date	Name	Comment
2014 ver.1.0	Jan. 7, 2015	USIBD	Release to Public
2016 ver.0.1	Apr. 4, 2016	USIBD	Pre-release for Public Review and Comment
2.0 - 2016	Oct. 10, 2016	USIBD	Release to Public

C220 Template Versioning:

Version	Date	Name	Comment
2014 ver.1.0	Jan. 7, 2015	USIBD	Release to Public
2016 ver.0.1	Apr. 4, 2016	USIBD	Pre-release for Public Review and Comment
2.0 - 2016	Oct. 10, 2016	USIBD	Release to Public

C320 Sample Versioning

Version	Date	Name	Comment
2014 ver.1.0	Jan. 7, 2015	USIBD	Release to Public
2.0 - 2016	Oct. 10, 2016	USIBD	Release to Public

Endorsement

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Exhibit 1 – LOA Specification

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Document C220™ ver. 2.0 - 2016
Level of Accuracy (LOA) Specification

IMPORTANT: Please read this note and delete this text box prior to using document

A Level of Accuracy (LOA) Specification Guide is associated with this document.

USIBD_SPC-LOA-guide_C120_2016_ver2.0.pdf

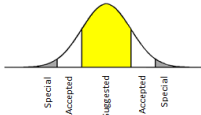*This Guide explains the processes and methodology needed to use this form efficiently. It is strongly suggested to read this Guide prior to using this specification framework.*

LEGEND

(yellow)	Suggested (Most commonly utilized)
(white)	Accepted (Commonly utilized)
(gray)	Special (Special case - may exceed most applications)
X	Specified (Specify chosen LOA by placing an X in the box)

Field of application ● Standard ○ Heritage
Dimensional units ● Imperial ○ Metric

Measured Validation
A = No data check
B = Check by overlapping data sets
C = Check by independet measurements or method

Represented Validation
A = No data check
B = Double check
C = Triple check

Measured Accuracy $ $$$$$

X	Absolute	If Absolute - describe reference frame here
	Relative	If Relative - describe measure of relativity here

Level of Accuracy (2 σ std dev)

-	2"	5/8"	1/4"	1/16"	Upper Range (Imperial)
2"	5/8"	1/4"	1/16"	0	Lower Range(Imperial)

Represented Accuracy $ $$$$$

X	Absolute	If Absolute - describe reference frame here
	Relative	If Relative - describe measure of relativity here

Level of Accuracy (2 σ std dev)

-	2"	5/8"	1/4"	1/16"	Upper Range (Imperial)
2"	5/8"	1/4"	1/16"	0	Lower Range(Imperial)

		CSI UniFormat™ 2010	LOA10	LOA20	LOA30	LOA40	LOA50	Validation	Note	LOA10	LOA20	LOA30	LOA40	LOA50	Validation	Note
A SUBSTRUCTURE									Exposed surface							Exposed surface
A10	Foundations								Exposed surface							Exposed surface
	A1010	Standard Foundations							Exposed surface							Exposed surface
	A1020	Special Foundations							Exposed surface							Exposed surface
A20	Subgrade Enclosures								Interior or Exposed Surface							Interior or Exposed Surface
	A2010	Walls for Subgrade Enclosures							Interior or Exposed Surface							Interior or Exposed Surface
A40	Slabs-on-Grade								Exposed surface							Exposed surface
	A4010	Standard Slabs on Grade							Exposed surface							Exposed surface
	A4020	Structural Slabs on Grade							Exposed surface							Exposed surface
B SHELL									Exposed surface							Exposed surface
B10	Superstructure								Exposed surface							Exposed surface
	B1010	Floor Construction							Specify Vertical / Horizontal Surface							Specify Vertical / Horizontal Surface
	B1020	Roof Construction							Specify Vertical / Horizontal Surface							Specify Vertical / Horizontal Surface
	B1080	Stairs							Specify Vertical / Horizontal Surface							Specify Vertical / Horizontal Surface
B20	Exterior Vertical Enclosures								Exposed Face							Exposed Face
	B2010	Exterior Walls							Exposed Face							Exposed Face
	B2020	Exterior Windows							Define Face required							Define Face required
	B2050	Exterior Doors and Grilles							Define Face required							Define Face required
	B2070	Exterior Louvers and Vents							Define Face required							Define Face required
	B2080	Exterior Walls and Appurtenances							Exposed Face							Exposed Face
	B2090	Exterior Walls Specialties							Exposed Face							Exposed Face
B30	Exterior Horizontal Enclosures								Exposed surface							Exposed surface
	B3010	Roofing							Exposed surface							Exposed surface
	B3020	Roof Apperurtenances							Exposed surface							Exposed surface
	B3040	Traffic Bearing Horizontal Enclosures							Exposed surface							Exposed surface
	B3060	Horizontal Openings							Define Face required							Define Face required
	B3080	Overhead Exterior Enclosures							Exposed surface							Exposed surface
C INTERIORS									Define Face required							Define Face required
C10	Interior Construction								Define Face required							Define Face required
	C1010	Interior Partitions							Define Face required							Define Face required
	C1020	Interior Windows							Define Face required							Define Face required
	C1030	Interior Doors							Define Face required							Define Face required
	C1040	Interior Grilles and Gates							Define Face required							Define Face required
	C1060	Raised Floor Construction							Exposed surface							Exposed surface
	C1070	Suspended Ceiling Construction							Exposed surface							Exposed surface
	C1090	Interior Specialties							Exposed Face							Exposed Face
C20	Interior Finishes								Exposed Face							Exposed Face
	C2010	Wall Finishes							Define Face required							Define Face required
	C2020	Interior Fabrications							Define Face required							Define Face required
	C2030	Flooring							Specify Vertical / Horizontal Surface							Specify Vertical / Horizontal Surface
	C2040	Stair Finishes							Specify Vertical / Horizontal Surface							Specify Vertical / Horizontal Surface
	C2050	Ceiling Finishes							Exposed surface							Exposed surface
D SERVICES									Exposed surface							Exposed surface
D10	Conveying								Define Face required							Define Face required
	D1010	Vertical Conveying Systems							Specify Vertical Surface							Specify Vertical Surface
	D1030	Horizontal Conveying							Specify Horizontal Surface							Specify Horizontal Surface
	D1050	Material Handling							Exposed surface							Exposed surface
	D1080	Operable Access Systems							Exposed surface							Exposed surface
D20	Plumbing								Exposed surface							Exposed surface
	D2010	Domestic Water Distribution							Exposed surface							Exposed surface
	D2020	Sanitary Drainage							Exposed surface							Exposed surface
	D2030	Building Support Plumbing Systems							Exposed surface							Exposed surface
	D2050	General Service Compressed-Air							Exposed surface							Exposed surface
	D2060	Process Support Plumbing Systems							Exposed surface							Exposed surface
D30	HVAC								Exposed surface							Exposed surface
	D3010	Facility Fuel Systems							Exposed surface							Exposed surface
	D3020	Heating Systems							Exposed surface							Exposed surface
	D3030	Cooling Systems							Exposed surface							Exposed surface
	D3050	Facility HVAC Distribution Systems							Exposed surface							Exposed surface
	D3060	Ventilation							Exposed surface							Exposed surface
	D3070	Special Purpose HVAC Systems							Exposed surface							Exposed surface
D40	Fire Protection								Exposed surface							Exposed surface
	D4010	Fire Suppression							Exposed surface							Exposed surface
	D4030	Fire Protection Specialties							Exposed surface							Exposed surface
D50	Electrical								Exposed surface							Exposed surface
	D5010	Facility Power Generation							Exposed surface							Exposed surface
	D5020	Electrical Service and Distribution							Exposed surface							Exposed surface
	D5030	General Purpose Electrical Power							Exposed surface							Exposed surface
	D5040	Lighting							Exposed surface							Exposed surface
	D5080	Miscellaneous Electrical Systems							Exposed surface							Exposed surface
D60	Communications								Exposed surface							Exposed surface
	D6010	Data Communications							Exposed surface							Exposed surface
	D6020	Voice Communications							Exposed surface							Exposed surface
	D6030	Audio-Video Communication							Exposed surface							Exposed surface
	D6060	Distributed Communications and Monitoring							Exposed surface							Exposed surface
	D6090	Communications Supplementary Components							Exposed surface							Exposed surface

Level 1 / Level 2 / Level 3

Code	Description								Surface								Surface
D70	Electronic Safety and Security								Exposed surface								Exposed surface
D7010	Access Control and Intrusion Detection								Exposed surface								Exposed surface
D7030	Electronic Surveillance								Exposed surface								Exposed surface
D7050	Detection and Alarm								Exposed surface								Exposed surface
D7070	Electronic Monitoring and Control								Exposed surface								Exposed surface
D7090	Electronic Safety and Security Supplementary Components								Exposed surface								Exposed surface
D80	Integrated Automation								Exposed surface								Exposed surface
D8010	Integrated Automation Facility Controls								Exposed surface								Exposed surface
E	**EQUIPMENT & FURNISHINGS**								Exposed surface								Exposed surface
E10	Equipment								Exposed surface								Exposed surface
E1010	Vehicle and Pedestrian Equipment								Exposed surface								Exposed surface
E1030	Commercial Equipment								Exposed surface								Exposed surface
E1040	Institutional Equipment								Exposed surface								Exposed surface
E1060	Residential Equipment								Exposed surface								Exposed surface
E1070	Entertainment and Recreational Equipment								Exposed surface								Exposed surface
E1090	Other Equipment								Exposed surface								Exposed surface
E20	Furnishings								Exposed surface								Exposed surface
E2010	Fixed Furnishings								Exposed surface								Exposed surface
E2050	Movable Furnishings								Exposed surface								Exposed surface
F	**SPECIAL CONSTRUCTION & DEMOLITION**								Exposed surface								Exposed surface
F10	Special Construction								Exposed surface								Exposed surface
F1010	Integrated Construction								Exposed surface								Exposed surface
F1020	Special Structures								Exposed surface								Exposed surface
F1030	Special Function Construction								Exposed surface								Exposed surface
F1050	Special Facility Components								Exposed surface								Exposed surface
F1060	Athletic and Recreational Special Construction								Exposed surface								Exposed surface
F1080	Special Instrumentation								Exposed surface								Exposed surface
F20	Facility Remediation								Exposed surface								Exposed surface
F2010	Hazardous Materials Remediation								Exposed surface								Exposed surface
F30	Demolition								Exposed surface								Exposed surface
F3010	Structure Demolition								Exposed surface								Exposed surface
F3030	Selective Demolition								Exposed surface								Exposed surface
F3050	Structure Moving								Exposed surface								Exposed surface
G	**BUILDING SITEWORK**								Exposed surface								Exposed surface
G10	Site Preparation								Exposed surface								Exposed surface
G1010	Site Clearing								Exposed surface								Exposed surface
G1020	Site Elements Demolition								Exposed surface								Exposed surface
G1030	Site Element Relocations								Exposed surface								Exposed surface
G1050	Site Remediation								Exposed surface								Exposed surface
G1070	Site Earthwork								Exposed surface								Exposed surface
G20	Site Improvements								Exposed surface								Exposed surface
G2010	Roadways								Exposed surface								Exposed surface
G2020	Parking Lots								Exposed surface								Exposed surface
G2030	Pedestrian Plazas and Walkways								Exposed surface								Exposed surface
G2040	Airfields								Exposed surface								Exposed surface
G2050	Athletic, Recreational, and Playfield Areas								Exposed surface								Exposed surface
G2060	Site Development								Exposed surface								Exposed surface
G2080	Landscaping								Exposed surface								Exposed surface
G30	Liquid and Gas Site Utilities								Exposed surface								Exposed surface
G3010	Water Utilities								Exposed surface								Exposed surface
G3020	Sanitary Sewage Utilities								Exposed surface								Exposed surface
G3030	Strom Drainage Utilities								Exposed surface								Exposed surface
G3050	Site Energy Distribution								Exposed surface								Exposed surface
G3060	Site Fuel Distribution								Exposed surface								Exposed surface
G3090	Liquid and Gas Site Utilizes Supplementary Components								Exposed surface								Exposed surface
G40	Electrical Site Improvements								Exposed surface								Exposed surface
G4010	Site Electrical Distribution Systems								Exposed surface								Exposed surface
G4050	Site Lighting								Exposed surface								Exposed surface
G50	Site Communications								Exposed surface								Exposed surface
G5010	Site Communications Systems								Exposed surface								Exposed surface
G90	Miscellaneous Site Construction								Exposed surface								Exposed surface
G9010	Tunnels								Exposed surface								Exposed surface