New Standard for New Era: Overview of the 2015 ASPRS Positional Accuracy Standards for Digital Geospatial Data

Visit http://www.asprs.org/Standards-Activities.html to view the new standards in its entirety.

The new ASPRS accuracy standards fill a critical need, vital for map users and makers alike. For centuries, map scale and contour interval have been used as an indication of map accuracy. Users want to know how accurately they can measure different things on a map, and map makers want to know how accurate maps need to be in order to satisfy user requirements. Those contracting for new maps depend on some form of map accuracy standard to evaluate the tradeoff between the accuracy required vs. how much time and expense are justified in achieving it, and then to describe the accuracy of the result in a uniform way that is reliable, defensible, and repeatable.

No prior U.S. accuracy standard comprehensively addresses the current state of mapping technology, which is why the new ASPRS standards were developed. The National Map Accuracy Standards (NMAS), developed in 1947, are still used because they are simple, but there is no scientific correlation with those standards and current mapping methodologies. The ASPRS 1990 Standards were an improvement over NMAS; however, they do not well represent the capabilities of lidar, orthoimagery, digital mapping cameras or other current technologies in wide-spread use today. The National Standard for Spatial Data Accuracy (NSSDA) is a reporting standard that references the old ASPRS 1990 standards and is cross-referenced in the new ASPRS standards, but it provides no accuracy thresholds and does not by itself provide any new or updated guidance on how to select or specify an appropriate accuracy for intended applications.

The new ASPRS Positional Accuracy Standards for Digital Geospatial Data address recent innovations in digital imaging and non-imaging sensors, airborne GPS, inertial measurement unit (IMU) and aerial triangulation (AT) technologies. Unlike prior standards, the new standards are independent of scale and contour interval, they address the higher level of accuracies achievable by the latest technologies (e.g. unmanned aerial systems and lidar mobile mapping systems), and they provide enough flexibility to be applicable to future technologies as they are developed. Finally, the new standards provide cross references to older standards, as well as detailed guidance for a wide range of potential applications.

INTRODUCTION

Effective in November, 2014, the *ASPRS Positional Accuracy Standards for Digital Geospatial Data* (2014) replaced the *ASPRS Accuracy Standards for Large-Scale Maps* (1990) and the *ASPRS Guidelines, Vertical Accuracy Reporting for Lidar Data* (2004). This standard was developed by the ASPRS Map Accuracy Standards Working Group, a joint committee under the Photogrammetric Applications Division, Primary Data Acquisition Division and Lidar Division, which was formed for the purpose of reviewing and updating ASPRS map accuracy standards to reflect current technologies. A subcommittee of this group, consisting of Dr. Qassim Abdullah, Dr. David Maune, Doug Smith, and Hans Karl Heidemann, was responsible for drafting the document. Draft versions of the standard underwent extensive review, both within ASPRS as well as through public review by other key geospatial mapping organizations, prior to final approval by the ASPRS Board of Directors on November 17, 2014. The new standard is available at: *http://www.asprs.org/Standards-Activities.html*: the ASPRS Standards web page. Readers can then navigate to the *ASPRS Positional Accuracy Standards for Digital Geospatial Data*.

Developed to address current technologies, this standard includes positional accuracy standards for digital orthoimagery, digital planimetric data, and digital elevation data. The standard follows metric measurement units to make it consistent with the international standards and practices. Accuracy classes, based on RMSE values, have been revised and upgraded from the 1990 standard to address the higher accuracies achievable with newer technologies. The standard also includes additional accuracy measures, such as orthoimagery seam lines, ground control accuracy, aerial triangulation accuracy, lidar relative swath-to-swath accuracy, recommended minimum Nominal Pulse Density (NPD), horizontal accuracy of elevation data, delineation of low confidence areas for vertical data, horizontal accuracy for elevation data, and the required number and spatial distribution of check points based on project area.

The standard addresses geo-location accuracies of geospatial products, and it is not intended to cover classification accuracy of thematic maps. Further, the standard does not specify the best practices or methodologies needed to meet the accuracy thresholds stated herein. The standard is intended to be used by geospatial data providers and users to specify the positional accuracy requirements for final geospatial products and to report data accuracies.

The standard defines accuracy classes based on RMSE thresholds for digital orthoimagery, digital planimetric data, and digital elevation data. It is limited in scope to addressing accuracy thresholds and testing methodologies for the most common mapping applications and to meet immediate shortcomings in the outdated 1990 and 2004 standards referenced above. The standard is intended to be technology independent and broad based, recognizing that limitations remain. It is intended to be the initial component upon which future work can build. Additional supplemental standards or modules should be pursued and added by subject matter experts in these fields as they are developed and approved by the ASPRS.

SPECIFIC REQUIREMENTS

Testing is always recommended but may not be required for all data sets; specific requirements must be addressed in the project specifications. When testing is required, horizontal accuracy shall be tested by comparing the planimetric coordinates of well-defined points in the data set with coordinates determined from an independent source of higher accuracy. Vertical accuracy shall be tested by comparing the elevations of the surface represented by the data set with elevations determined from an independent source of higher accuracy. This is done by comparing the elevations of the checkpoints with elevations interpolated from the data set at the same x/y coordinates.

All accuracies are assumed to be relative to the published datum and ground control network used for the data set and as specified in the metadata. Ground control and checkpoint accuracies and processes should be established based on project requirements. Unless specified to the contrary, it is expected that all ground control and check points should normally follow the guidelines for network accuracy as detailed in the Geospatial Positioning Accuracy Standards, Part 2: Standards for Geodetic Networks, Federal Geodetic Control Subcommittee, Federal Geographic Data Committee (FGDC-STD-007.2-1998). When local control is needed to meet specific accuracies or project needs, it must be clearly identified both in the project specifications and the metadata.

Horizontal accuracy is to be assessed using root-mean-square-error (RMSE) statistics in the horizontal plane, i.e., $RMSE_x$, $RMSE_y$, and $RMSE_r$. Vertical accuracy is to be assessed in the z dimension only. For vertical accuracy testing, different methods are used in non-vegetated terrain (where errors typically follow a normal distribution suitable for RMSE statistical analyses) and vegetated terrain (where errors do not necessarily follow a normal distribution). When errors cannot be represented by a normal distribution, the 95th percentile value more fairly estimates accuracy at a 95% confidence level. For these reasons vertical accuracy is to be assessed using $RMSE_z$ statistics in non-vegetated terrain and 95th percentile statistics in vegetated terrain. Elevation data sets shall also be assessed for horizontal accuracy where possible.

With the exception of vertical data in vegetated terrain, error thresholds stated in this standard are presented in terms of the maximum acceptable RMSE value. Corresponding estimates of accuracy at the 95% confidence level values are computed using *National Standard for Spatial Data Accuracy* (NSSDA) methodologies and are subject to the limitations that the data be normally distributed and with systematic bias removed such that the mean error of the data is small.

ACCURACY REQUIREMENTS FOR AERIAL TRIANGULATION AND GROUND CONTROL POINTS

The standard introduces for the first time accuracy measures for the ground control used in aerial triangulation and for the results of the aerial triangulation itself. The standard distinguishes between accuracy requirements for the ground control based on the final products derived from the process. Two different requirements are specified, those are:

- Accuracy of ground control designed for planimetric data (orthoimagery and/or digital planimetric map) production only:
  $RMSE_x$ or $RMSE_y = ¼ * RMSE_{x(Map)}$ or $RMSE_{y(Map)}$,
  $RMSE_z = ½ * RMSE_{x(Map)}$ or $RMSE_{y(Map)}$
- Accuracy of ground control designed for elevation data, or planimetric data and elevation data production:
  $RMSE_x$, $RMSE_y$ or $RMSE_z = ¼ * RMSE_{x(Map)}$, $RMSE_{y(Map)}$ or $RMSE_{z(DEM)}$

As for the measure of accuracy for aerial triangulation, the standard also based it on the intended final products derived from the process. Two different requirements are specified, those are:

- Accuracy of aerial triangulation designed for digital planimetric data (orthoimagery and/or digital planimetric map) only:
  $RMSE_{x(AT)}$ or $RMSE_{y(AT)} = ½ * RMSE_{x(Map)}$ or $RMSE_{y(Map)}$
  $RMSE_{z(AT)} = RMSE_{x(Map)}$ or $RMSE_{y(Map)}$ of orthoimagery
- Accuracy of aerial triangulation designed for elevation data, or planimetric data (orthoimagery and/or digital planimetric map) and elevation data production:
  $RMSE_{x(AT)}$, $RMSE_{y(AT)}$or $RMSE_{z(AT)} = ½ * RMSE_{x(Map)}$, $RMSE_{y(Map)}$ or $RMSE_{z(DEM)}$

HORIZONTAL ACCURACY STANDARDS FOR GEOSPATIAL DATA

Table 1 specifies the primary horizontal accuracy standard for digital data, including digital orthoimagery, digital planimetric data and scaled planimetric maps. This standard defines horizontal accuracy classes in terms of their $RMSE_x$ and $RMSE_y$ values. While prior ASPRS standards used numerical ranks for discrete accuracy classes tied directly to map scale (i.e., Class 1, Class 2, etc.), many modern applications require more flexibility than these classes allowed. For example, using the new standard, a Scope of work, could specify that digital orthoimagery, digital planimetric data, or scaled maps must be produced to meet ASPRS Accuracy Standards for 7.5 cm $RMSE_x$ and $RMSE_y$ Horizontal Accuracy Class.

This standard does not associate product accuracy with the ground sample distance (GSD) of the source imagery, pixel size of the orthoimagery, or map scale for scaled maps. Due to the digital nature of today's geospatial data and the different architectures and configuration of aerial sensors, many applications of horizontal accuracy cannot be tied directly to compilation scale, resolution of the source imagery or final pixel resolution. The relationship between the recommended $RMSE_x$ and $RMSE_y$ accuracy class and the orthoimagery pixel size varies depending on the imaging sensor characteristics and the specific mapping processes used. The appropriate horizontal accuracy class must be negotiated and agreed upon between the end user and the data provider, based on specific project needs and design criteria. Table 2 presents examples of 24 horizontal accuracy classes and associated quality criteria as related to digital orthoimagery.

Additional tables in the full standard, not included in this highlight article, provide the most common associations that have been established (based on user's interpretation and past technologies) to relate orthoimagery pixel size to map scale and the ASPRS 1990 legacy standard map accuracy classes; and general guidelines to determine the appropriate orthoimagery accuracy class for three

Table1. Horizontal Accuracy Standards for Geospatial Data

Horizontal Accuracy Class	**Absolute Accuracy**			**Orthoimagery Mosaic Seamline Mismatch (cm)**
	$RMSE_x$ and $RMSE_y$ cm)	**$RMSE_r$ (cm)**	**Horizontal Accuracy at 95% Confidence Level (cm)**	
X-cm	≤*X*	≤1.414**X*	≤2.448**X*	≤ 2**X*

Table 2. Common Horizontal Accuracy Classes for Digital Orthoimagery

Horizontal Accuracy Class RMSE$_x$ and RMSE$_y$(cm)	RMSE$_r$ (cm)	Orthoimage Mosaic Seamline Maximum Mismatch (cm)	Horizontal Accuracy at the 95% Confidence Level (cm)
0.63	0.9	1.3	1.5
1.25	1.8	2.5	3.1
2.5	3.5	5.0	6.1
5.0	7.1	10.0	12.2
7.5	10.6	15.0	18.4
10.0	14.1	20.0	24.5
12.5	17.7	25.0	30.6
15.0	21.2	30.0	36.7
17.5	24.7	35.0	42.8
20.0	28.3	40.0	49.0
22.5	31.8	45.0	55.1
25.0	35.4	50.0	61.2
27.5	38.9	55.0	67.3
30.0	42.4	60.0	73.4
45.0	63.6	90.0	110.1
60.0	84.9	120.0	146.9
75.0	106.1	150.0	183.6
100.0	141.4	200.0	244.8
150.0	212.1	300.0	367.2
200.0	282.8	400.0	489.5
250.0	353.6	500.0	611.9
300.0	424.3	600.0	734.3
500.0	707.1	1000.0	1223.9
1000.0	1414.2	2000.0	2447.7

different levels of geospatial accuracy for (1) highest accuracy work, (2) standard mapping and GIS work, and (3) visualization and less accurate work.

VERTICAL ACCURACY STANDARDS FOR ELEVATION DATA

Three new terms are introduced: (1) Non-vegetated Vertical Accuracy (NVA) based on RMSE statistics in non-vegetated terrain; (2) Vegetated Vertical Accuracy (VVA) based on 95th percentile statistics in vegetated terrain; and (3) low confidence areas. The naming convention for each vertical accuracy class is directly associated with the RMSE expected from the product in non-vegetated terrain. Table 3 provides the vertical accuracy classes naming convention for any digital elevation data. Horizontal accuracy requirements for elevation data are specified and reported independent of the vertical accuracy requirements.

The Non-vegetated Vertical Accuracy at the 95% confidence level in non-vegetated terrain (NVA) is approximated by multiplying the accuracy value of the Vertical Accuracy Class (or RMSE$_{z)}$ by 1.9600. This calculation includes survey checkpoints located in traditional open terrain (bare soil, sand, rocks, and short grass) and urban terrain (asphalt and concrete surfaces). The NVA, based on an RMSE$_z$ multiplier, should be used only in non-vegetated terrain where elevation errors typically follow a normal error distribution. RMSE$_z$-based statistics should not be used to estimate vertical accuracy in vegetated terrain or where elevation errors often do not follow a normal distribution.

The Vegetated Vertical Accuracy at the 95% confidence level in vegetated terrain (VVA) is computed as the 95th percentile of the absolute value of vertical errors in all vegetated land cover categories combined, including tall weeds and crops, brush lands, and fully forested areas. For all vertical accuracy classes, the VVA standard is 3.0 times the accuracy value of the Vertical Accuracy Class.

Both the RMSE$_z$ and 95th percentile methodologies specified above are currently widely accepted in standard practice and have been proven to work well for typical elevation data sets derived from current technologies. However, both methodologies have limitations, particularly when the number of check points is small. As more robust statistical methods are developed and accepted, they will be added as new Annexes to supplement and/or supersede these existing methodologies.

Table 3. Vertical Accuracy Standards for Digital Elevation Data

Vertical Accuracy Class	Absolute Accuracy			Relative Accuracy (where applicable)		
	RMSE$_z$ Non-Vegetated (cm)	NVA at 95% Confidence Level (cm)	VVA at 95th Percentile (cm)	Within- Swath Hard Surface Repeatability (Max Diff) (cm)	Swath-to-Swath Non-Vegetated Terrain (RMSD$_z$) (cm)	Swath-to-Swath Non-Vegetated Terrain (Max Diff) (cm)
X-cm	≤*X*	≤1.96**X*	≤3.00**X*	≤0.60**X*	≤0.80**X*	≤1.60**X*

If the VVA standard cannot be met, low confidence area polygons shall be developed and explained in the metadata. For elevation data derived from imagery, the low confidence areas would include vegetated areas where the ground is not visible in stereo. For elevation data derived from lidar, the low confidence areas would include dense cornfields, mangrove or similar impenetrable vegetation. The low confidence area polygons are the digital equivalent to using dashed contours in past standards and practice. Annex C of the full standard outlines specific guidelines for implementing low confidence area polygons.

Table 4 lists 10 common vertical accuracy classes and their corresponding accuracy values and other quality measures according to this standard. Additional tables in the full standard, not included in this highlight article, provides the equivalent vertical accuracy measures for the same ten classes according to the legacy standards of ASPRS 1990 and NMAS of 1947, and examples of vertical accuracy and the recommended lidar points density for digital elevation data according to the new ASPRS 2014 standard.

HORIZONTAL ACCURACY REQUIREMENTS FOR ELEVATION DATA

New to the geospatial community, the standard specifies horizontal accuracy thresholds for two types of digital elevation data with different horizontal accuracy requirements:

- **Photogrammetric elevation data:** For elevation data derived using stereo photogrammetry, the horizontal accuracy equates to the horizontal accuracy class that would apply to planimetric data or digital orthoimagery produced from the same source imagery, using the same aerial triangulation/INS solution.
- **Lidar elevation data:** Horizontal error in lidar derived elevation data is largely a function of positional error as derived from the Global Navigation Satellite System (GNSS), attitude (angular orientation) error (as derived from the INS), and flying altitude; and can be estimated based on these parameters. The following equation provides an estimate for the horizontal accuracy for the lidar-derived data set assuming that the positional accuracy of the GNSS, the attitude accuracy of the Inertial Measurement Unit (IMU) and the flying altitude are known:

$$Lidar\ Horizontal\ Error(RMSE_r) = \sqrt{(GNSS\ positional\ error)^2 + \left(\frac{\tan(IMU\ error)}{0.55894170} x\ flying\ altitude\right)^2}$$

SUMMARY

The main standard on the ASPRS portal includes additional information on the following:

- References
- Terms and definitions
- Symbols, abbreviated terms and notations
- Assumptions regarding systematic errors and acceptable mean error
- Horizontal accuracy requirements for elevation data
- Low confidence areas for elevation data
- Accuracy requirements for aerial triangulation and INS-based sensor orientation of digital imagery
- Accuracy requirements for ground control used for aerial triangulation
- Checkpoint accuracy and placement requirements
- Checkpoint density and distribution
- Relative accuracy of lidar and IFSAR data
- Positional accuracy reporting

Annex A - Background and Justifications
Annex B - Data Accuracy and Quality Examples
Annex C - Accuracy Testing and Reporting Guidelines
Annex D - Accuracy Statistics and Example

CITATION

ASPRS, 2014. ASPRS Positional Accuracy Standards for Digital Geospatial Data, *Photogrammetric Engineering & Remote Sensing*, Volume 81, No. 3, 53 p., URL: *http://www.asprs.org/Standards-Activities.html.*

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Table 4. Vertical Accuracy/Quality Examples for Digital Elevation Data

Vertical Accuracy Class	Absolute Accuracy			Relative Accuracy (where applicable)		
	$RMSE_z$ Non-Vegetated (cm)	NVA at 95% Confidence Level (cm)	VVA at 95th Percentile (cm)	Within-Swath Hard Surface Repeatability (Max Diff) (cm)	Swath-to-Swath Non-Veg Terrain ($RMSD_z$) (cm)	Swath-to-Swath Non-Veg Terrain (Max Diff) (cm)
1-cm	1.0	2.0	3	0.6	0.8	1.6
2.5-cm	2.5	4.9	7.5	1.5	2	4
5-cm	5.0	9.8	15	3	4	8
10-cm	10.0	19.6	30	6	8	16
15-cm	15.0	29.4	45	9	12	24
20-cm	20.0	39.2	60	12	16	32
33.3-cm	33.3	65.3	100	20	26.7	53.3
66.7-cm	66.7	130.7	200	40	53.3	106.7
100-cm	100.0	196.0	300	60	80	160
333.3-cm	333.3	653.3	1000	200	266.7	533.3

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[1] The method presented here is one approach; there other methods for estimating the horizontal accuracy of lidar data sets, which are not presented herein. Abdullah, Q., 2014, unpublished data