



ASPRS Positional Accuracy Standards for Digital Geospatial Data

(EDITION 2, VERSION 1.0 - AUGUST 2023)

Foreword

Edition 1 of the ASPRS Positional Accuracy Standards for Digital Geospatial Data was published in November 2014. In the years since, users expressed concerns and suggested revisions based on their experience applying the Standards in real-world situations. In addition, technologies have evolved in such a way as to challenge the assumptions upon which Edition 1 was based.

In 2022, ASPRS established a formal Positional Accuracy Standards Working Group under the Standards Committee to evaluate user comments, consider technology advancements, and implement appropriate changes to the Standards. The following individuals were appointed to the Positional Accuracy Standards Working Group:

Chair: Dr. Qassim Abdullah, Vice President and Chief Scientist, Woolpert, Inc.

Members:

- Dr. Riadh Munjy, Professor of Geomatics Engineering, California State University, Fresno
- Josh Nimetz, Senior Elevation Project Lead, U.S. Geological Survey
- Michael Zoltek, National Geospatial Programs Director, GPI Geospatial, Inc.
- Colin Lee, Photogrammetrist, Minnesota Department of Transportation

The ASPRS Positional Accuracy Standards for Digital Geospatial Data are designed to be modular in nature, such that revisions could be made and additional sections added as geospatial technologies and methods evolve. Additionally, the Standards are designed to recommend best practices, methods, and guidelines for the use of emerging technologies to achieve the goals and requirements set forth in the Standards. With support from the ASPRS Technical Divisions, the primary Working Group established subordinate Working Groups to author Addenda for best practices and guidelines for photogrammetry, lidar, UAS, and field surveying. The subordinate Working Group members and contributors are credited in each Addendum, as appropriate.

Summary of Changes in Edition 2

Important changes adopted in Edition 2 of the Standards are as follows:

1. Eliminated references to the 95% confidence level as an accuracy measure.

- **Reason for the change:** The 95% confidence measure of accuracy for geospatial data was introduced in the National Standard for Spatial Data Accuracy (NSSDA) published by the Federal Geographic Data Committee in 1998. This measure was carried forward in the ASPRS Guidelines for Vertical Accuracy Reporting for Lidar Data published in 2004, as well as in Edition 1 of the ASPRS Positional Accuracy Standards for Digital Geospatial Data published in 2014. However, RMSE is also a way to express data accuracy, and it is typically reported alongside the 95% confidence level because the two are derived from the same error distribution. As a matter of fact, users need to compute RMSE first in order to obtain the 95% confidence measure. The reporting of two quantities representing the same accuracy at different confidence levels has created confusion for users and data producers alike.

- **Justification for the change:** The RMSE is a reliable statistical term that is sufficient to express product accuracy, and it is well understood by users. Experience has shown that the use of both RMSE and the 95% confidence level leads to confusion and misinterpretation.

2. Relaxed the accuracy requirement for ground control and checkpoints.

- **Reason for the change:** Edition 1 called for ground control points of four times the accuracy of the intended final product, and ground checkpoints of three times the accuracy of the intended final product. With goals for final product accuracies approaching a few centimeters in both the horizontal and vertical, it becomes difficult, if not impossible, to use RTK methods for control and checkpoint surveys, introducing a significant burden of cost for many high-accuracy projects.

Photogrammetric Engineering & Remote Sensing
Vol. 89, No. 10, October 2023, pp. 589-592.
0099-1112/22/589-592

© 2023 American Society for Photogrammetry
and Remote Sensing
doi: 10.14358/PERS.89.10.589

- **Justification for the change:** As the demand for higher-accuracy geospatial products grows, accuracy requirements for the surveyed ground control and checkpoints set forth in Edition 1 exceed those that can be achieved in a cost-effective manner, even with high-accuracy GPS. Furthermore, today's sensors, software, and processing methods have become very precise, diminishing the errors introduced in data acquisition and processing. If best practices are followed, safety factors of three and four times the intended product accuracy are no longer needed.

3. Required the inclusion of survey checkpoint accuracy when computing the accuracy of the final product.

- **Reason for the change:** Since checkpoints will no longer need to meet the three-times-intended-product accuracy requirement (see item 2 above), the error in the checkpoints survey may no longer be ignored when reporting the final product accuracy. This is especially important, given the increasing demand for highly accurate products—which, in some cases, approach the same order of magnitude as the survey accuracy of the checkpoints. Therefore, checkpoint error should be factored into the final product accuracy assessment that is used to communicate the reliability of resulting final products.
- **Justification for the change:** Errors in the survey checkpoints used to assess final product accuracy, although small, can no longer be neglected. As product accuracy increases, the impact of error in checkpoints on the computed product accuracy increases. When final products are used for further measurements, calculations, or decision making, the reliability of these subsequent measurements can be better estimated if the uncertainty associated with the checkpoints is factored in.

4. Removed the pass/fail requirement for Vegetated Vertical Accuracy (VVA) for lidar data.

- **Reason for the change:** Data producers and data users have reported that they are challenged in situations where Non-Vegetated Vertical Accuracy (NVA) is well within contract specifications, but VVA is not. As explained below, factors affecting VVA are not a function of the lidar system accuracy; therefore, only NVA should be used when making a pass/fail decision for the overall project. VVA should be evaluated and reported, but should not be used as a criterion for acceptance.
- **Justification for the change:** Where lidar can penetrate to bare ground under trees, the accuracy of the points, as a function of system accuracy, should be comparable to lidar points in open areas. However, the accuracy and the quality of lidar-derived surface under trees is affected by:
 1. the type of vegetation where it affects the ability of lidar pulse to reach the ground,

2. the density of lidar points reaching the ground,
3. and the performance of the algorithms used to separate ground and above-ground points in these areas.

Furthermore, the accuracy of the ground checkpoints acquired with GPS surveying techniques in vegetated areas is affected by restricted satellite visibility. As a result, accuracies computed from the lidar-derived surface in vegetated areas are not valid measures of lidar system accuracy.

5. Increased the minimum number of checkpoints required for product accuracy assessment from 20 to 30.

- **Reason for the change:** In Edition 1, a minimum of 20 checkpoints are required for testing positional accuracy of the final mapping products. This minimum number is not based on rigorous science or statistical theory; rather, it is a holdover from legacy Standards and can be traced back to the National Map Accuracy Standards published by the U.S. Bureau of the Budget in 1947.
- **Justification for the change:** The Central Limit Theorem calls for at least 30 samples to calculate statistics such as mean, standard deviation, and skew. These statistics are relied upon in positional accuracy assessments. According to The Central Limit Theorem, regardless of the distribution of the population, if the sample size is sufficiently large ($n \geq 30$), then the sample mean is approximately normally distributed, and the normal probability model can be used to quantify uncertainty when making inferences about a population based on the sample mean. Therefore, in Edition 2, a product accuracy assessment must have a minimum number of 30 checkpoints in order to be considered fully compliant.

6. Limited the maximum number of checkpoints for large projects to 120.

- **Reason for the change:** Since these Standards recognize the Central Limit Theorem as the basis for statistical testing, there is insufficient evidence for the need to increase the number of checkpoints indefinitely as the project area increases. The new maximum number of checkpoints is equal to four times the number called by the Central Limit Theorem.
- **Justification for the change:** According to the old guidelines, large projects require hundreds, sometimes thousands of checkpoints to assess product accuracy. Such numbers have proven to be unrealistic for the industry, as it inflates project budget and, in some cases, hinders project executions, especially for projects taking place in remote or difficult-to-access areas.

7. Introduced a new accuracy term: "three-dimensional positional accuracy."

- **Reason for the change:** Three-dimensional models require consideration of three-dimensional accuracy,

rather than separate horizontal and vertical accuracies. Edition 2 endorses the use of the following three terms:

- Horizontal positional accuracy
- Vertical positional accuracy
- Three-dimensional (3D) positional accuracy

- **Justification for the change:** Three-dimensional models and digital twins are gaining acceptance in many engineering and planning applications. Many future geospatial data sets will be in true three-dimensional form; therefore, a method for assessing positional accuracy of a point or feature within the 3D model is needed to support future innovation and product specifications.

8. Added Best Practices and Guidelines Addenda for:

- General Best Practices and Guidelines
- Field Surveying of Ground Control and Checkpoints
- Mapping with Photogrammetry
- Mapping with Lidar
- Mapping with UAS

This summarizes the most significant changes implemented in Edition 2 of the ASPRS Positional Accuracy Standards for Digital Geospatial Data. Other minor changes will be noted throughout.

TABLE OF CONTENTS

Foreword

Summary of Changes in Edition 2

Foreword to Edition 1 of 2014

1. Purpose

- 1.1 Scope and Applicability
- 1.2 Limitations
- 1.3 Structure and Format

2. Conformance

3. References

4. Authority

5. Terms and Definitions

6. Symbols, Abbreviated Terms, and Notations

7. Specific Requirements

- 7.1 Statistical Assessment of Accuracy
- 7.2 Systematic Error and Mean Error Assumptions
- 7.3 Horizontal Positional Accuracy Standard for Geospatial Data
- 7.4 Vertical Positional Accuracy Standard for Elevation Data
- 7.5 Three-Dimensional Positional Accuracy Standard for Geospatial Data
- 7.6 Horizontal Accuracy of Elevation Data
- 7.7 Low Confidence Areas in Elevation Data
- 7.8 Accuracy Requirements for Aerial Triangulation and IMU-Based Sensor Orientation
- 7.9 Accuracy Requirements for Ground Control Used for Aerial Triangulation
- 7.10 Accuracy Requirements for Ground Control Used for Lidar
- 7.11 Positional Accuracy Assessment of Geospatial Data Products
 - 7.11.1 First Component of Positional Error – Product Fit to Checkpoints
 - 7.11.2 Second Component of Positional Error – Survey Control and Checkpoint Error
 - 7.11.3 Horizontal Positional Accuracy
 - 7.11.4 Vertical Positional Accuracy
 - 7.11.5 Three-dimensional Positional Accuracy
- 7.12 Checkpoint Accuracy and Placement
- 7.13 Checkpoint Density and Distribution

7.14 Data Internal Precision (Relative Accuracy) of Lidar and IFSAR Data

- 7.14.1 Within-Swath (Smooth-Surface) Precision
- 7.14.2 Swath-to-Swath Precision

7.15 Accuracy Reporting

- 7.15.1 Accuracy Reporting by Data User or Consultant
- 7.15.2 Accuracy Reporting by Data Producer

Appendix A — Background and Justifications (Informative)

- A.1 Legacy Standards and Guidelines
- A.2 A New Standard for a New Era
 - A.2.1 Mapping Practices During the Film-based Era
 - A.2.2 Mapping Practices During the Softcopy Photogrammetry Era
 - A.2.3 Mapping Practices During the Digital Sensors Photogrammetry Era

Appendix B — Data Accuracy and Quality Examples (Normative)

- B.1 Aerial Triangulation and Ground Control Accuracy Examples
- B.2 Digital Orthoimagery Horizontal Accuracy Classes
- B.3 Digital Planimetric Data Horizontal Accuracy Classes
- B.4 Digital Elevation Data Vertical Accuracy Classes
- B.5 Relating ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023 Values to Legacy ASPRS 1990 Accuracy Values
 - Example 1: Relating the Horizontal Accuracy of a Map or Orthorectified Image calculated with the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023 to the Legacy ASPRS Map Standards of 1990
 - Example 2: Relating the Vertical Accuracy of an Elevation Data Set calculated with the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023 to the Legacy ASPRS Map Standards of 1990

B.6 Relating ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023 Values to Legacy NMAS 1947 Accuracy Values

Example 3: Relating the Horizontal Accuracy of a Map or Orthorectified Image calculated with the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023 to the Legacy National Map Accuracy Standards of 1947

Example 4: Relating the Vertical Accuracy of an Elevation Data Set calculated with the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023 to the Legacy National Map Accuracy Standards of 1947

B.7 Relating ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023 Values to the FGDC National Standard for Spatial Data Accuracy (NSSDA)

Example 5: Relating the Horizontal Accuracy of a Map or Orthorectified Image calculated with ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023 to the FGDC National Standard for Spatial Data Accuracy (NSSDA)

Example 6: Relating the Vertical Accuracy of an Elevation Data Set calculated with the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023 to the FGDC National Standard for Spatial Data Accuracy (NSSDA)

B.8 Estimating Horizontal Accuracy of Lidar Data

B.9 Elevation Data Accuracy vs. Elevation Data Quality

Appendix C — Accuracy Testing and Reporting Guidelines (Normative)

- C.1 Checkpoint Requirements
- C.2 Accuracy of Checkpoints
- C.3 Number of Checkpoints
- C.4 Distribution of Vertical Checkpoints Across Land Cover Types
- C.5 Vertical Checkpoints
- C.6 Horizontal Checkpoints for Elevation Data
- C.7 Testing and Reporting of Product Accuracy
 - C.7.1 Testing and Reporting Horizontal Accuracy of Digital Orthophotos and Planimetric Maps
 - C.7.2 Testing and Reporting of Vertical Accuracy of Elevation Data
- C.8 Low Confidence Areas
- C.9 Erroneous Checkpoints
- C.10 Data Internal Precision Assessment
- C.11 Interpolation of Elevation Represented Surface for Checkpoint Comparisons

Appendix D — Accuracy Statistics and Example (Normative)

- D.1 Reporting Accuracy Statistics
 - D.1.1 Accuracy Computations

ADDENDUM I: General Best Practices and Guidelines

ADDENDUM II: Best Practices and Guidelines for Field Surveying of Ground Control and Checkpoints

ADDENDUM III: Best Practices and Guidelines for Mapping with Photogrammetry

ADDENDUM IV: Best Practices and Guidelines For Mapping With Lidar

ADDENDUM V: Best Practices and Guidelines For Mapping With UAS

FIGURES

- Figure C.1 Topographic Surface Represented as a TIN
- Figure C.2 Topographic Surface Represented as a DEM

TABLES

- Table 7.1 Horizontal Accuracy Classes for Geospatial Data
- Table 7.2 Vertical Accuracy Classes for Digital Elevation Data
- Table 7.3 Three-Dimensional Accuracy Classes for Geospatial Data
- Table 7.4 Computing Vertical Product Accuracy
- Table A.1 Common Photography Scales using Camera with 9" Film Format and 6" Lens
- Table A.2 Relationship Between Film Scale and Derived Map Scale
- Table B.1 Aerial Triangulation and Ground Control Accuracy Requirements- For Orthoimagery and/or Planimetric Data Only
- Table B.2 Aerial Triangulation and Ground Control Accuracy Requirements- For Orthoimagery and/or Planimetric Data and Elevation Data
- Table B.3 Common Horizontal Accuracy Classes According to the New Standard
- Table B.4 Horizontal Accuracy/Quality Examples for High Accuracy Digital Planimetric Data
- Table B.5 Vertical Accuracy/Quality Examples for Digital Elevation Data
- Table B.6 Vertical Accuracy of the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023 Compared to Legacy Standards
- Table B.7 Examples of Vertical Accuracy and Recommended Lidar Point Density for Digital Elevation Data according to the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, 2023
- Table B.8 Estimated Horizontal Error (RMSEH) as a Function of GNSS Error, IMU Error, and Flying Height
- Table C.1 Recommended Number of Checkpoints for Horizontal Accuracy and NVA Testing Based on Project Area
- Table C. 2 Low Confidence Area Criteria Min NPD: Minimum Nominal Point Density, Max NPS: Maximum Nominal Point Spacing Min NGPD: Minimum Nominal Ground Point Density, Max NGPS: Maximum Nominal Ground Point Spacing
- Table D.1 Accuracy Statistics for Example Data