**TO: ASPRS Map Accuracy Working Group**

**FROM: HCS**

**DATE: 10/30/2014**

The following are my thoughts on ASPRS\_Positional\_Accuracy\_Standards\_for\_Digital\_Geospatial\_Data\_Draft\_Rev6\_V1\_Highlighted.docx . I address my comments to each topic by line number.

Line 98+ (Terms and Definitions), ASPRS “recognizes” 15 different definitions of “accuracy”. I think that ASPRS should help clean up this minefield of terms by sticking to only a few, such as:

* Absolute Accuracy = Positional accuracy with respect to a real-world georeference. This can be with respect to a horizontal datum (horizontal accuracy) or a vertical datum (vertical accuracy), and it would be expressed as RMSE (root mean square error) and is identical to “standard deviation” (68.26% confidence interval). This is related to “absolute positioning” as it is used to move data to a georeference.
* Relative Accuracy = Positional accuracy with respect to another object in the same database. This is related to “relative positioning” as it is used in Public Works (position a pipe with respect to a curb). This can be horizontal or vertical.
* I would do away with definitions for local accuracy, mean error, network accuracy, positional error, positional accuracy, etc.
* I would do away with “radial accuracy” = Combined accuracy from those in the X, Y, and Z directions, where each may be different. In the case of expressing it as an RMSEr, it would be called RMSExy or RMSExyz,as applicable.
* I would separate these definitions from any ones developed for LiDAR (VVA, etc.).
* I would bring in a standard table that clearly relates sigma multiplication factors with confidence intervals, or some table extract that provides multipliers for 90%, 95% and 99%.
* I would clearly separate the confidence intervals. That means that RMSE is 68.26% (RMSE\*1), 90% is RMSE\*1.645, 95% is RMSE\*1.960, 2\*RMSE is 95.44% ci, etc.

Line 159, Skew. See my comments at the end of this document. Skewness is necessary in a treatise of statistics, but may not be necessary in a practical document on mapping accuracy. It so happens that, in mapping, almost all test samples are small (due to costs), and most small samples are skewed. That is the reason Gauss introduced the correction factor in the formula for sigma (and therefore RMSE). Furthermore, if a skewed sample passes the RMSE test, how is one going to reject it? Also see what I mention for Line 290.

Line 222, testing. It is, in principle, most likely wrong to use “the same points” (line 225) for horizontal and vertical testing. Horizontal testing should be done with “horizontally well-defined points”, and the other with “vertically well-defined points”. Especially in projects where LiDAR and imagery data were collected, vertical testing should be done where LiDAR points were collected (over a level surface, for example).

Line 232, guidelines. I would even go further: Put the horse in front of the wagon and leave the selection of the ground control accuracies to the contractor to suit a specific project result. For example, it is practical to specify that a certain project “shall result in an orthomap with a nominal GSD of 3cm, with an accuracy of ±12cm at 95% ci”. Note that your whole document does not use the softening “nominal”. Also, it does not show the obligatory “±” (necessitated by the “R” in RMSE). Finally, a project may have various results (urban, rural, forests, etc.) which all may have different accuracies, each with their own sentence like the one I underlined for each data layer (start thinking “GIS”).

Line 230, metadata. There should be a strong message that says that “once the accuracy requirements for a project are published, it becomes imperative that they be included in a metafile that accompanies each product delivery”. That would document decisions made regarding accuracy.

Line 239, check points. Elsewhere in the document there is a table providing control accuracy multipliers that contradict this paragraph. I think that the accuracy of test points has to be the same as that for ground control points.

Line 248, elevations. That is not correct. The problem lies with the definition of what a vertical well-defined point is. Every photogrammetrist knows that this means a more or less level and wide surface that can be used to determine elevation (or a suitable target), or what the next paragraph states at Line 250.

Line 269, accuracy. This whole paragraph is not right. RSME can easily be expressed as an error ellipsoid, which reflects sigmax, sigmay, and sigmaz, even if the survey method is different. This ellipsoid, as a whole, can be scaled up or down to reflect 90%, 95% or 99%. This is especially true for testing. Therefore one obtains a vertically elongated ellipsoid (like a football standing on its end, ready for kick-off). Any spherical statement like i.e. RMSEr would be less meaningful).

Line 278, LiDAR. At present, LiDAR is used in conjunction with imaging to create large-area orthomaps. For this purpose, imaging (with block adjustment) is used as a horizontal data source, and LiDAR as a vertical data source. They have to march in lock step to make sure that the orthorectification process uses a DEM that is in the right place. It is hard to separate the two, especially for small GSDs.

A tangent of mine (applicable to the document as a whole). Presently there are enough projects that use AGPS/IMU-generated perspective center data (position and look direction) as “ground control” during block adjustment, with subsequent use of ground check points. Strip leveling is refined after LiDAR swaths are edited by adjusting their position (something like side laps). In other words, the whole process relies heavily on the AGPS/IMU solution, which this whole document on accuracy ignores. What are the guidelines for AGPS/IMU accuracy? This is worse if one ignores the things that one needs to do to provide certain desired results, such as payload calibration (GPS antenna vs. sensor perspective centers, IMU borehole calibration, etc.). Sorry, but you asked. Actually, PE&RS has Chinese papers on some of this.

Line 290, kurtosis, skew, bias. Since this standard introduces them for the first time in mapping, both of these statistical results would only be meaningful if they would be accompanied by their meaning within the mapping sciences. My thinking on these topics is the following:

* Bias in mapping is really a one, two or three-dimensional shift of a sample as a whole, as in the case of applying the wrong datum, the bias then being the difference between the ground control mean and the sample mean.
* Skew in mapping is the presence of a warped dataset, either in the check points or in the dataset being tested. This can happen if a dataset is exposed to affine transformations by untrained staff. As such, it is an important measure in mapping, and should be part of test result reporting. The standard lacks guidelines for this. Also, see my notes for Line 159 above.
* One significant meaning of kurtosis in mapping is the presence of a dataset portions that were georeferenced to slightly different ground control (from partial datum shifts to flying with two or more AGPS/IMU units).

295, 25%. What is this? A double project standard? Is that RMSE/4? No court will accept this language. I suggest that this paragraph be removed.

296, documentation. The results of any discussion on error should ALWAYS be documented in a project metafile, and in contract documents.

Line 337, ground control. If this is simplified to RMSEx/3,RMSEy/3 and RMSEz/3, then the message is more generic and can easily include convergent and non-vertical imagery.

Line 351, 7.7. I would move the discussion of LiDAR accuracy elsewhere. Besides, the present document presents information on LiDAR that is chopped up and all over the place.

Line 375, Table 7.1. Does not jive with content presented previously in Line 239.

Line 413, 7.9. Could that not be brought together with previous discussions of vertical accuracy?

Line 423, Lidar elevation data. This sections needs to be cleaned up. First it talks about INU error, but the formula does not mention it. Flying altitude is really generated from ellipsoidal and orthometric heights. Besides, are you sure that the formula is not missing a square root, as it applies to all error propagation calcs? Besides, the units have to be the same (all errors have to reflect the same confidence interval - i.e. it should say “GNSS RMSEr” and “IMU RMSEr”).

Line 770, Table B.3. I am not sure of the purpose of this table could not just be replaced with this one (and the numbers are called “multipliers”, applicable to all the units possible – I removed the “cm”):

|  |  |  |  |
| --- | --- | --- | --- |
| **Horizontal Accuracy Class RMSEx and RMSEy** | **RMSEr** | **Orthoimage Mosaic Seamline Maximum Mismatch** | **Horizontal Accuracy at the 95% Confidence Level** |
| 1 | 1.4 | 2.1 | 2.4 |

Why is the third column not labeled as “RMSE”? Also, this could easily be replaced with a graph of four straight lines. Or, is the intent really to talk about, for example, a “27.50 class”? Who wants to keep track of 24 classes? The same comments apply to some extent to Table B.7 (Line 819).

Line 1317, Sx. I see that the equation deos include the Gaussian correction factor, so that small sample evaluations are less affected by skewed samples.

Line 1343. RMSE. How about introducing the same Gaussian correction factor into the RMSE equation?

Line 1364, Computation. Interesting example, but showing a project with a vertical accuracy that is 1.6 times better than the horizontal one. Wow.

Line 1421, Percentiles. What is the practical need for this, if we already have RMSE and confidence intervals?

**Other comments**

Bias. Over the years, I have tried to come to grips of the various statistical terms that affect mapping. My (not 100%) conclusions are that statistical terms need to be explained within a mapping context, especially because (a) there is a plethora of terms, and (b) most of them are misused. My (not ironclad) interpretations are the following, as applied to a block adjustments, Helmert transformations, etc.:

* Each pass, tie, and control point will, after achieving a least squares best fit, show residuals, which express the remaining X, Y, and Z errors for each point. There residuals are called Vx, Vy and Vz. One gets one (and only one) Vi per observation equation.
* A set of numbers that combines all these Vi residuals into one set of numbers is called the Root Mean Square Error (RMSE) and may appear as any combination of RMSEx, RMSEy, RMSEz, RMSExy or RMSExyz. This is the sample spread in terms of error distribution and expresses the quality of fit between one data set and another. This is a measure of precision, not accuracy.
* Another set of numbers that results from least squares adjustments is the precision of the calculation of unknowns. These numbers are called standard deviations of the unknowns, and are found in variance-covariance matrices that result from the adjustments. These are numbers that should be inspected after these calculations, but no customer does. They are related not to the data points and observation equations, but to the adjustment unknowns, such as the following:
* The perspective centers and space angles of each image in a block, or
* Scale, shifts and rotations in transformations.
* If a dataset ends up in China instead of the US, then there is a bias. This bias is not a result of least squares adjustments (bias is actually eliminated by them). This is the actual accuracy of a dataset.
* See my thinking on skew for Line 159 and 290.
* See my thinking on kurtosis on Line 290.
* I saw that the well-accepted rules on contour and spot elevation accuracies went away. I would definitely leave them in there.

By the way, the title on page iv should be “Foreword” and not “Forward”.

Bottom Line

My overall impression is that we went from nothing to something significantly overdesigned. Therefore I suggest these actions:

1. Reduce this to one clear message about precision and accuracy;
2. Split photogrammetry and LiDAR into two documents;
3. Reduce the document to something that fits on 2-3 pages, so it can be waved around in the courts;
4. Put everything else into appendices, including history, formulae and samples; and
5. In the main document leave only practical, simple-to-use, and down-to-earth guidelines and procedures.

Well, “you asked”. I hope this helps. I would be interested in reactions.

Sincerely,

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