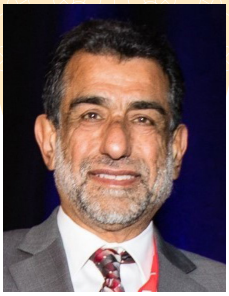

MAPPINGMATTERS

YOUR QUESTIONS ANSWERED

The layman's perspective on technical theory and practical applications of mapping and GIS

BY Qassim A. Abdullah, Ph.D., PLS, CP**

QUESTION:

Question: For one of our projects, we have been asked to provide an orthorectified imagery product with a horizontal accuracy of 10cm at 95% confidence, according to the ASPRS Positional Accuracy Standards for Digital Geospatial Data of 2014. The questions I have are the following:

1. What is the ground sampling distance (GSD) of the imagery we need to collect and use to meet the required accuracy?
2. What is the accuracy of the ground control points we need for the aerial triangulation?
3. What is the accuracy of aerial triangulation we need to meet?
4. Can we use RTK surveying techniques to survey the needed ground control points?

Dr. Srini Dharmapuri CP, PMP, GISP, Sanborn

Dr. Abdullah: First, I would like to reiterate the design philosophy that the new ASPRS Positional Accuracy Standards for Digital Geospatial Data of 2014 was based upon, and that is that the standards are sensor agnostic and data driven. With this philosophy, the standards do not endorse the use of GSD, contour interval or map scale to express product accuracy. Product accuracy should be determined by user need and the fidelity and quality of the product generation process. Certain imagery resolution can be used to produce orthorectified products with different accuracies based on the production process used, quality and number of ground control points, and the quality and accuracy of the digital elevation model used in the orthorectification process. Another good reason for not associating product accuracy with imagery resolution is the various designs of today's digital cameras. Film-based aerial cameras were designed with one film format/size (9 inches or 229mm) and one lens focal length (6 inches or 152mm), which enabled us to predict product accuracy based on film scale or flying altitude. Digital aerial cameras are made with a variety of charge-coupled device (CCD) array size and lenses that make it impossible to adopt one accuracy figure for all of them based on the flying altitude or imagery ground resolution. Table 1 illustrates this issue as it lists the flying altitudes for six well-known digital cameras, all set to acquire imagery with 15cm resolution. The table shows the wide range of altitudes (1,440m to 3,538m above ground level, or AGL) used for different cameras to acquire the same 15cm imagery.

Table 1. Digital cameras and flying altitude.

Sensor	Flying Altitude (m)	Flying Altitude (ft)
UltraCAM CONDOR (100mm)	3,261	10,698
ULTRACAM EAGLE MARK III (92mm)	3,450	11,319
DMC III (92mm)	3,538	11,609
ADS100 (62.5mm)	1,875	6,152
PhaseONE 190MP	2,935	9,629
ADS80	1,440	4,725

While products from these cameras are expected to meet the highest accuracy when a stringent photogrammetric workflow is followed, one needs to be extra careful when dealing with imagery acquired from a very high altitude. Errors in the final products caused by the residual errors in the computed exterior-orientation parameters, especially the sensor attitudes (i.e. omega, phi and kappa), are linearly proportional to the flying altitude. Table 2 lists the degree of error expected in a product

Table 2. Relationship between flying altitude and product horizontal accuracy.

Flying Altitude AGL (ft)		Horizontal Error in X or Y (ft)	
ft	meter	ft	cm
100.0	30.5	0.007	0.22
150.0	45.7	0.011	0.33
200.0	61.0	0.015	0.44
400.0	121.9	0.029	0.89
3,000.0	914.4	0.218	6.65
6,000.0	1,828.8	0.436	13.30
10,000.0	3,048.0	0.727	22.17

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“The new Accuracy Standards for Digital Geospatial Data of 2014 are sensor agnostic and data driven. It does not endorse the use of GSD, contour interval or map scale to express product accuracy.”

using inaccurate sensor altitudes, as determined by an aerial triangulation that is accurate to 15 arc seconds.

Table 2 clearly demonstrates why products from unmanned aircraft systems (UAS) flown from an altitude of 45 meters are expected to be more accurate than products flown from an altitude of 3,048 meters using manned aircraft.

Now that I have explained the problem with associating product accuracy with imagery resolution, let me respond to your questions:

1) **What is the imagery GSD you need to request to meet the 10cm accuracy threshold?**

   Before I answer this question, let us convert your accuracy figure from 95% confidence level to root mean square error (RMSE) so it is compatible with ASPRS accuracy standards. The ASPRS standard in Section B.7 provides the following conversion formula:

   Accuracy at 95% or $Accuracy_r = 2.4477 \times RMSE_x = 2.4477 \times RMSE_y$

   Therefore,

   $RMSE_x$ or $RMSE_y$ = Accuracy at 95% / 2.4477, or

   $RMSE_x$ or $RMSE_y$ = 10cm / 2.4477 = 4.085cm

Again, ASPRS does not provide exact correlation between product accuracy and imagery resolution for the reasons I outlined earlier. However, the ASPRS standards provided guidelines for the users to be followed during the transition period from the legacy ASPRS standards of 1990 to the new standards. Table B.5 of the standards, also partially provided in Table 3, provides recommendations on the orthoimagery pixel sizes and the associated accuracy classes. These are largely based on experience with current sensor technologies and primarily apply to large- and medium-format metric cameras. The table is only provided as a guideline for users during the transition period to the new standards. These associations may change in the future as mapping technologies continue to advance and evolve. As you see in Table 3 and based on our experience with digital cameras, users on a regular basis obtained accuracy that is equivalent to two times the GSD and, in some cases, one GSD if extra efforts were exerted during the production process. Based on this, you can propose the acquisition of imagery with a GSD of 8cm or even 4cm if needed. I do not recommend the latter GSD of 4cm as it is a risky practice that may jeopardize your ability to deliver products with an accuracy of 4cm.

“RTK surveying techniques will not meet these requirements and you will need to use traditional surveying techniques or static GPS for horizontal coordinates and differential leveling for height survey or the combination of the two”

Table 3 digital orthoimagery accuracy examples for current large and medium format metric cameras.

Common Orthoimagery Pixel Sizes	Recommended Horizontal Accuracy Class $RMSE_x$ and $RMSE_y$ (cm)	Orthoimage $RMSE_x$ and $RMSE_y$ in terms of pixels	Recommended use
1.25cm	≤1.3	≤1 pixel	Highest accuracy work
	2.5	2 pixels	Standard mapping and GIS work
	≥3.8	≥3 pixels	Visualization and less accurate work
2.5cm	≤2.5	≤1 pixel	Highest accuracy work
	5.0	2 pixels	Standard mapping and GIS work
	≥7.5	≥3 pixels	Visualization and less accurate work
5cm	≤5.0	≤1 pixel	Highest accuracy work
	10.0	2 pixels	Standard mapping and GIS work
	≥15.0	≥3 pixels	Visualization and less accurate work
7.5cm	≤7.5	≤1 pixel	Highest accuracy work
	15.0	2 pixels	Standard mapping and GIS work
	≥22.5	≥3 pixels	Visualization and less accurate work
15cm	≤15.0	≤1 pixel	Highest accuracy work
	30.0	2 pixels	Standard mapping and GIS work
	≥45.0	≥3 pixels	Visualization and less accurate work

2) **What is the accuracy of the ground control points you need for the aerial triangulation?**

ASPRS standards require the accuracy for the ground control points to meet the following criteria:

a. The accuracy of ground control designed for planimetric data (orthoimagery and/or digital planimetric map) production **only**:

$RMSE_x$ or $RMSE_y = 1/4 * RMSE_{x(Map)}$ or $RMSE_{y(Map)}$,

$RMSE_z = 1/2 * RMSE_{x(Map)}$ or $RMSE_{y(Map)}$

b. The accuracy of ground control designed for elevation data, or planimetric data and elevation data production:

$RMSE_x$, $RMSE_y$ or $RMSE_z = 1/4 * RMSE_{x(Map)}$, $RMSE_{y(Map)}$ or $RMSE_{z(DEM)}$

According to the above requirements, here are the accuracy figures for the ground control points for your project:

a. To produce orthos and planimetric map ONLY: Accuracy of ground control $RMSE_x$ or $RMSE_y$ = 1cm

Accuracy of ground control $RMSE_z$ = 2cm

b. To produce orthos, planimetric maps and digital elevation models:

Accuracy of ground control $RMSE_x$, RMSE*y* or $RMSE_z$ = 1cm, assuming that the accuracy of the derived elevation data is also expected to meet an RMSEz of 4cm.

Film-based aerial cameras were designed with one film format/size (9 inches or 229mm) and one lens focal length (6 inches or 152mm), which enabled us to predict product accuracy based on film scale or flying altitude."

3) **What is the accuracy of aerial triangulation you need to meet?**

ASPRS standards require the following accuracy for aerial triangulation:

a. The accuracy of aerial triangulation designed for planimetric data (orthoimagery and/or digital planimetric map) production **only**:

$RMSE_{x(AT)}$ or $RMSE_{y(AT)} = 1/2 * RMSE_{x(Map)}$ or $RMSE_{y(Map)}$,

$RMSE_{z(AT)} = RMSE_{x(Map)}$ or $RMSE_{y(Map)}$

b. The accuracy of ground control designed for elevation data, or planimetric data and elevation data production:

"Digital aerial cameras are made with a variety of CCD array size and lenses that make it impossible to adopt one accuracy figure for all of them based on the flying altitude or imagery ground resolution"

$RMSE_{x(AT)}$, $RMSE_{y(AT)}$ or $RMSE_{z(AT)} = 1/2 * RMSE_{x(Map)}$, $RMSE_{y(Map)}$ or $RMSE_{z(DEM)}$

According to the above requirements, here are the accuracy figures for aerial triangulation for your project:

a. To produce orthos and planimetric maps ONLY:

$RMSE_{x(AT)}$ or $RMSE_{y(AT)}$ = 2cm

$RMSE_{z(AT)}$ = 4cm

b. To produce orthos, planimetric maps and digital elevation models:

$RMSE_x$, $RMSE_y$ or $RMSE_z$ = 2cm, assuming that the accuracy of the derived elevation data is also expected to meet an $RMSE_z$ of 4cm.

4) **Can we use RTK surveying techniques to survey the needed ground control points?**

RTK field surveying techniques usually result in an accuracy of about 2cm horizontally and 3cm vertically (as RMSE or one sigma). Considering the 1cm accuracy requirement for the ground control points needed for your product, RTK surveying techniques will not meet these requirements and you will need to use traditional surveying techniques or static GPS for horizontal coordinates and differential leveling for height survey or the combination of the two.

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