LiDAR Mapping Systems

Survey Ground Control Recommendations

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1. Introduction

This document provides an overview of ground control recommendations based on the 2014 ASPRS Positional Accuracy Standards for Digital Geospatial Data in order to properly collect ground control for digital orthoimagery and LiDAR-derived digital elevation data.

Note that this document is not intended to replace the ASPRS document, and the published document of standards should be thoroughly reviewed to verify specific project requirements. Accuracy testing is always recommended, but may not be required for all data sets. Specific project control requirements must be addressed in the project specifications prior to data acquisition.

2. Horizontal vs. Vertical Control

Surveyed ground control is used in two ways - horizontal control and vertical control.

2.1 Vertical Control

Airborne and UAV-based LiDAR derived products use surveyed ground points to control and test absolute vertical accuracy. “Vertical accuracy shall be tested by comparing the elevations of the surface represented by the [LiDAR] data set with elevations determined from an independent source of higher accuracy. This is done by comparing the elevations of surveyed checkpoints with elevations interpolated from the data set at the same x/y coordinates” (ASPRS, 2014, p.A6).

Vertical control “shall be established at locations that minimize interpolation errors when comparing elevations interpolated from the data set to the elevations of the checkpoints” (ASPRS, 2014, p. A8). Vertical control “shall be surveyed on flat or uniformly-sloped open terrain and with slopes of 10% or less and should avoid vertical artifacts or abrupt changes in elevation” (ASPRS, 2014, p.A8). The GNSS control locations require a clear and unobstructed view of the sky, away from nearby power lines, cars, buildings, or other objects that could cause electromagnetic or multipath interference.

2.2 Horizontal Control

When testing is required for imagery, “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” (ASPRS, 2014, p.A6).

Figure 1. Aerial Target

Horizontal survey control shall be established at well-defined points, like at the center of an aerial target as shown in Figure 1 above. “A well-defined point represents a feature for which the horizontal position can be measured to a high degree of accuracy and position with respect to the geodetic datum. For the purpose of accuracy testing, well-defined points must be easily visible or identifiable on the ground, on the independent source of higher accuracy, and on the product itself” (ASPRS, 2014, p.A8). For testing orthoimagery, well-defined points shall not be selected on any elevated features, as elevated targets are subject to relief displacement which causes any objects above the ground to lean away from the principal point of the photograph.

It is important to note that surveyed control points are not suited to estimate absolute horizontal accuracy in lidar derived elevation data. The reason for this stems from data resolution. Pointcloud data is inherently sparse, compared to high resolution raster datasets like RGB imagery. For example, in RGB imagery, an 1 square meter aerial target within an image footprint is represented by hundreds, if not thousands of pixels, where that same target could only be represented by a few ground return points depending on the mission’s target point density per square meter. Instead, “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”(ASPRS, 2014, p.A7).

3. Ground Control Points (GCPs) vs. Survey Checkpoints (SCPs)

There are two ways to differentiate high accuracy survey control points - Ground Control Points (GCPs) and Survey Checkpoints (SCPs).

Survey checkpoints are points with known coordinates that are used to validate the accuracy of the survey. GCPs leverage GNSS data to adjust survey models and improve their overall accuracy. Unlike GCPs, checkpoints do not affect how the survey is processed in any way. GCPs and SCPs are generally collected at the same time, using the same methodology. Simply put, GCPs are surveyed control points used for data adjustments, and SCPs are surveyed control points used for accuracy reporting. GCPs utilized for data adjustments should not be used to validate the accuracy of the data product.

4. Number and Distribution of Survey Control

When testing is needed, the distribution of the checkpoints will be project specific and must be determined by mutual agreement between the data provider and the end user. In no case shall absolute accuracy of LiDAR derived elevation data or digital orthoimagery accuracy be based on less than 20 checkpoints (ASPRS, 2014, p.A9).

According to ASPRS 2014, p.A19, a minimum of 20 Non-vegetated Vertical Accuracy (NVA) and 5* Vegetated Vertical Accuracy (VVA) checkpoints should be collected for sites smaller than 500 square kilometers. An additional 5 VVA checkpoints should be collected for sites between 501-750 sq km.

*No VVA checkpoints required for orthoimagery

4.1 Land Cover Types - NVA vs. VVA

All GCPs should be NVA checkpoints, whereas SCPs can be NVA and/or VVA checkpoints. These points should be collected at least 1 meter away from any sharp terrain changes (i.e. curbs, cliffs, severe slopes)

Note: checkpoints collected in vegetated areas are less reliable than checkpoints collected on hard surfaces and can often result in decreased reportable accuracies, as shown in Figure 2 below.

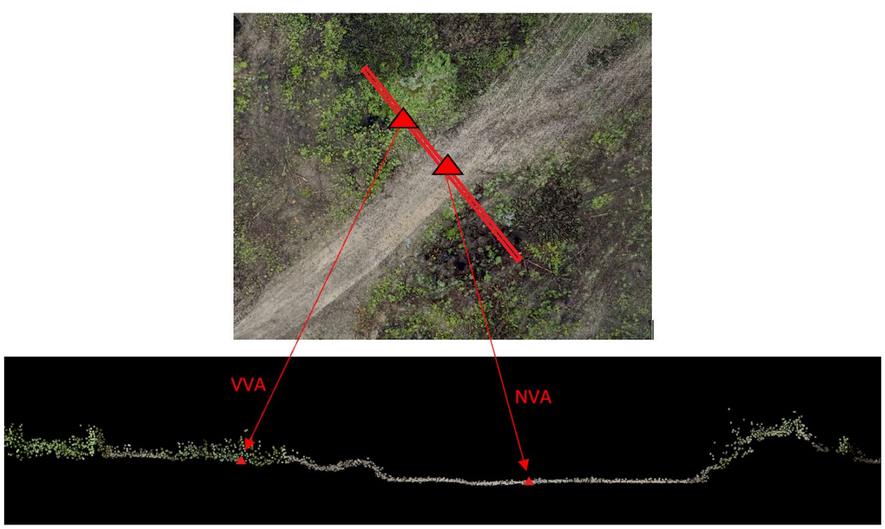

Figure 2. NVA surveyed point on a hard surface road and a VVA surveyed point within low vegetation

- (NVA) Non-vegetated vertical accuracy checkpoints:Survey checkpoints located in traditional open terrain (hard bare soil) and urban terrain (asphalt and concrete surfaces)

- (VVA) Vegetated vertical accuracy checkpoints: Survey checkpoints are located in areas like tall weeds, crops, and brush lands.

Both the total number of points and spatial distribution of checkpoints play an important role in the accuracy evaluation of any geospatial data. ASPRS specifies clear guidelines for the number of checkpoints, and, in some cases, the land-cover types, however, there are no clear guidelines available for defining and/or characterizing the spatial distribution of the GCPs and SCPs. As a rule of thumb, points should be distributed proportionally within the project area with hard surfaces primarily targeted as shown in the figure below.

Phoenix LiDAR Systems also recommends that if more than one UAV mission is required for collection of the area of interest, that checkpoints are distributed within each mission, especially within areas of overlap between missions.

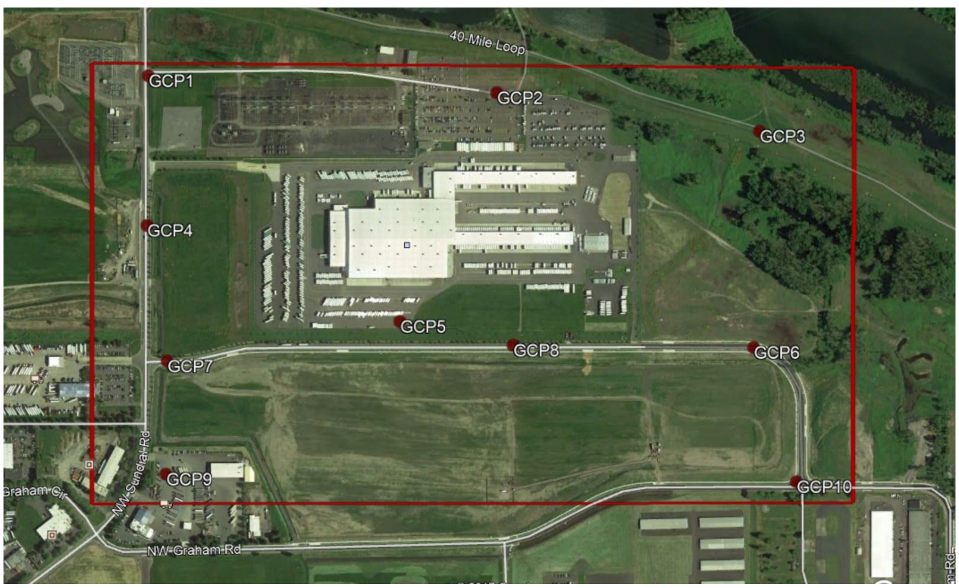

Figure 3. Rectangular project area with well distributed surveyed control on hard ground features

5. GCP and SCP Collection - RTK Surveying

A high accuracy and high efficiency approach to collecting GCPs and SCPs is through RTK surveying. RTK stands for Real-Time Kinematic and is a technique that uses carrier-based ranging and provides ranges (and therefore positions) that are orders of magnitude more precise than those available through code-based positioning. RTK surveying requires two GNSS receivers, a static reference station commonly referred to as a “base” and a receiver that moves around freely known as the “rover”. RTK techniques are complicated, but the basic concept is to reduce and remove errors common to a base station and rover pair.

The purpose of the reference station is to send correction data to the rover via a radio link, while maintaining a fixed and/or known position. The rover is then capable of producing a position with centimeter-level accuracy (typically 1-3 cm) using the received corrections. This relationship is depicted below in Figure 4.

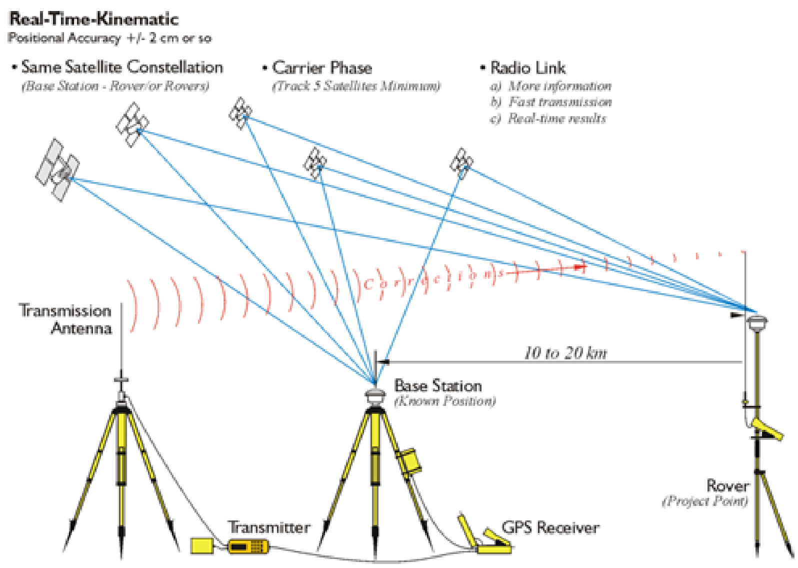

Figure 4. Real-Time-Kinematic

A high precision GNSS reference station should be used to create a static point in, or near, the study area. The survey control locations are measured relative to the static ground station, allowing the high accuracies obtained by the long static session to be used to correct the rover points.

An easy example to illustrate how RTK positioning works, is to think about a person holding a kite string connected to a kite. The person represents the base, the kite string represents the “baseline”, or distance between base and rover, and the kite flying in the air represents the rover. If the position of the person is known and does not move, and the kite string is fixed to the kite, the kite position can be determined no matter which position the kite is flown.

6. Static Reference Station

You can utilize the same reference station for both the LiDAR survey and the RTK survey. Before starting either survey, set up the reference station in an area with a clear view of the sky and away from obstacles like cars, buildings, and trees. The height of the instrument (HI) should also be measured at this time. The HI should be measured from the ground, or benchmark, to the Antenna Reference Point (ARP). The static reference station needs to be set to record at an interval of 1hz. At least two hours of data should be collected by the static station to ensure proper location refinement.

7. References

"Positional Accuracy Standards for Digital Geospatial Data", American Society for Photogrammetry and Remote Sensing (ASPRS), 2014

http://www.asprs.org/wp-content/uploads/2015/01/ASPRS_Positional_Accuracy_Standards_Edition1_Version100_November2014.pdf.

This content is subject to change.

If you have any questions about this document, please contact Phoenix LiDAR Systems by sending a message to support@phoenixlidar.com.