

Using LiDAR Derived Ground Control Points for Imagery Inspection



APFO Geospatial Services Branch - Service Center Support Section

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Abstract

Since 2006, the Aerial Photography Field Office (APFO) has been compiling a database of ground control points (GCPs). These points are mainly used to assess the horizontal accuracy of USDA imagery programs. Most of the points have been acquired through a gratis basis via federal and state agencies. Points that are loaded into the database must meet some basic requirements: a *stated* accuracy of 1 meter or better, a point description and or supplemental data, and the point location must be photo-identifiable on a 1 meter resolution image. As of January 2012, the database contains approximately 41,000 points. The first five years of creating and maintaining the database required a lot of networking in the geospatial community to locate control points; now, most of the existing resources have “dried up” and the database is in a research and maintenance phase. The research involves locating control point resources. One of the potential resources is control points derived from light detection and ranging (LiDAR) data. This paper will provide an analysis of using control derived from LiDAR and the potential impacts this may have on specifications, standards, and methodology. The point of this paper is not to discuss the pros and cons of LiDAR data acquisition, storage, or processing, but how the derivative products can be applied to extracting ground control points for use in imagery inspection.

Introduction

In 2003, the National Agriculture Imagery Program (NAIP) began in earnest. The intent of the program was to acquire imagery during the peak agricultural growing seasons and deliver ortho rectified products to the USDA county service centers to assist with farm programs and maintenance of Common Land Unit (CLU) polygons. A large part of APFO's role in NAIP is to inspect the imagery that is contracted for the program. When the original NAIP inspection process was created there were two major aspects: image quality inspection and horizontal accuracy inspection. At the time, the horizontal accuracy inspection involved checking the NAIP imagery against older imagery datasets (usually mosaicked digital ortho rectified USGS quadrangles (MDOQs)). This methodology was specified in the NAIP contract as contractors were required to spatially match the NAIP imagery to the MDOQs. This contract specification was loosely termed "relative" horizontal accuracy. In 2006, it was decided that the horizontal accuracy of NAIP imagery should be based on an "absolute" specification. The NAIP contract was then amended to include the specification that "95% of all points tested shall be within 6 meters of true ground". This was based on the horizontal accuracy standard from the National Standard for Spatial Data Accuracy (NSSDA). By 2009, all states receiving NAIP imagery had migrated to the "absolute" specification.

In order to facilitate this new method of inspecting the horizontal accuracy of NAIP, quality ground control points were needed. Since 2007, the Service Center Support Section (SCSS) has worked diligently to obtain, inspect, and input the control points into a database for the purpose of imagery inspection (see figure 1). As of 2011, each state in the continental United States now has control point coverage; some states have more dense point concentrations than others (figure 2). As it has become more difficult to locate new control point resources, the SCSS is now looking into alternate sources for ground control points in areas where coverage and density is low or non-existent. One of these options is using points derived from LiDAR data.

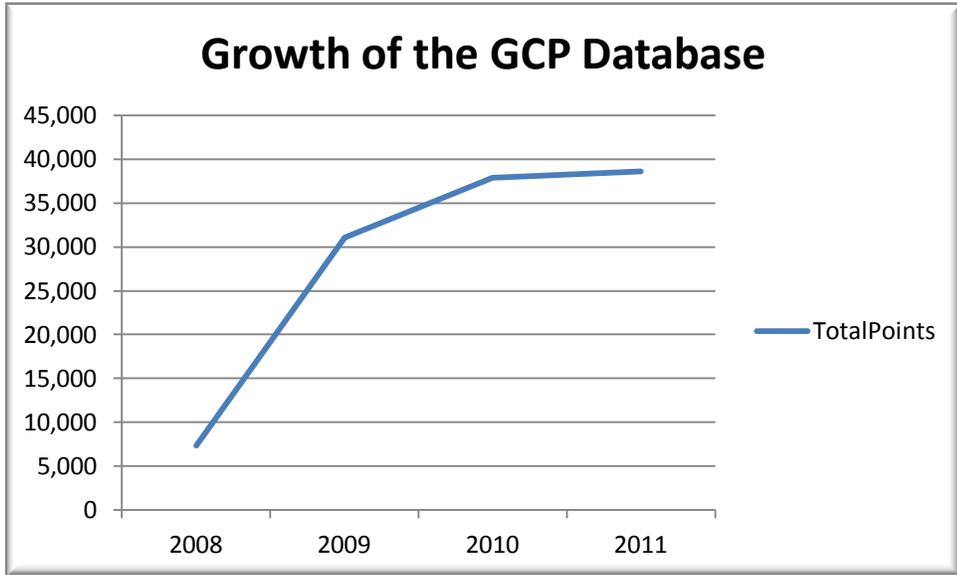


Figure 1: Growth of the Control Point Database

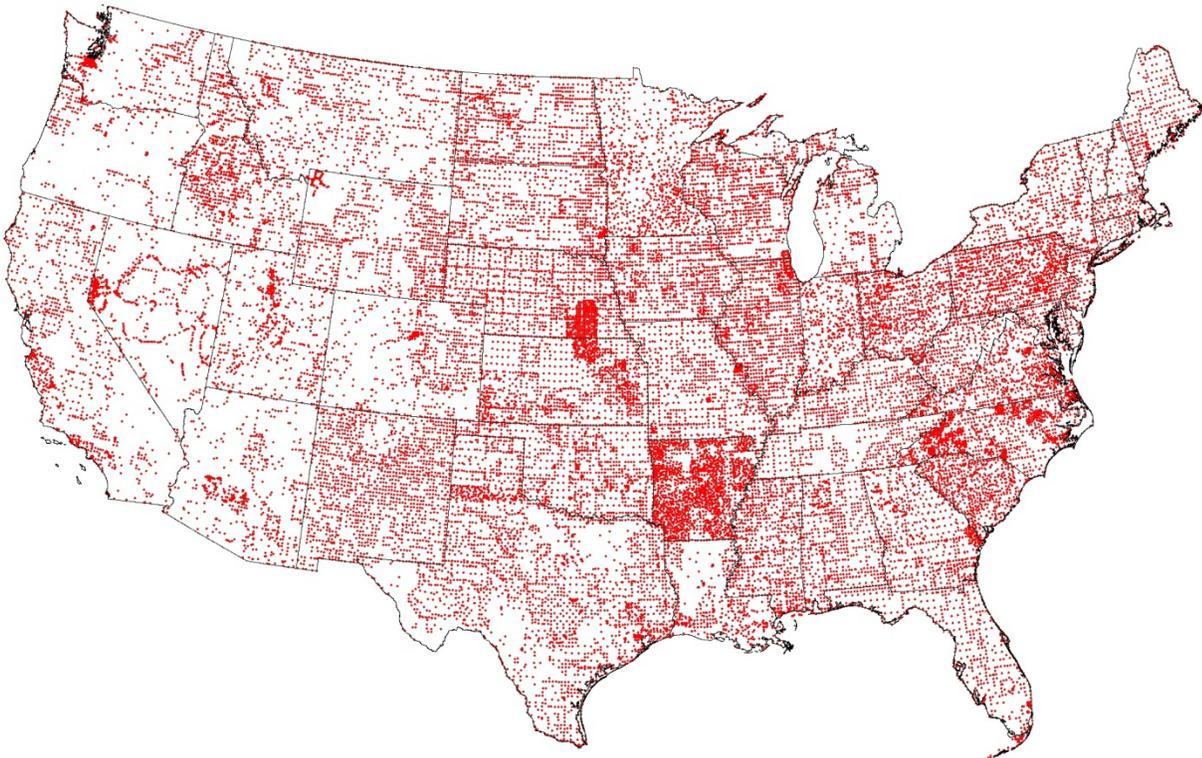


Figure 2: Location of ground control points

What is LiDAR?

LiDAR is remote sensing technology that can measure the distance to, or other properties of, a target by illuminating the target with light, using pulses from a laser. By precisely measuring the return time of the laser pulse, the “range” can be calculated using the speed of light. LiDAR scanners are capable of emitting up to 150,000 or more pulses per second with up to 5 return values per pulse. Typically, the final return from a pulse represents “bare earth”. The technology has been around since the mid-1980s, but only over the past five years or so, has it been applied to geospatial functions. These include urban modeling, feature extraction, mapping bare earth surfaces, tree identification, and road delineation. The “raw” data from the LiDAR sensor is usually output to an ASCII file with x, y, and z values transformed into a coordinate system. The data sets are typically quite large and require enough data storage and computing power to handle the amount of data. A small file can contain millions of points. The ASCII file(s) can be converted into what is known as a “LAS” file. A LAS file is simply an industry standard binary file used to exchange LiDAR point data between end users. Once the data has been processed into a “manageable” form, derivative products such as elevation, surface models, and intensity images (figure 3) can be created. The intensity image is a raster that includes values that are measurements of the return signal strength. Intensity values are relative rather than absolute and vary with altitude, atmospheric conditions, directional reflectance properties, and the reflectivity of the target. Because these values are relative, the process of creating images from vector intensity data requires the exercise of good judgment. LiDAR intensity images have orthogonal geometry characteristics and usually have a high spatial resolution (1 meter or better). Ground objects and photo-identifiable features can be identified from an intensity image that corresponds to an aerial image and therefore, the intensity image could be a good alternative for ground control collection.



Figure 3: Intensity image derived from LiDAR points

Deriving Control Points from Intensity Images

As stated before, intensity images are based on relative values as opposed to absolute values. Control points in the APFO database are referred to as absolute, so there is some hesitation in deriving a control point from a relative source. However, if the known source has a high horizontal accuracy, then perhaps it is worth considering. Generally speaking, LiDAR acquisitions have a stated horizontal accuracy of plus/minus one foot. Many of the points in our database have a stated accuracy of 50 centimeters to one meter, so for the purpose of this paper, the higher accuracy intensity images derived from the LiDAR data will be considered as a relative control source. There are a couple of ways to derive a control point from the intensity images. Either the points can be derived by a person or the points are auto extracted using image processing software.

Selecting and digitizing an identifiable feature requires a quality intensity image. In 2010, the Oregon Department of Parks and Recreation contracted for a LiDAR acquisition in the Cottonwood Canyon area of Gilliam and Sherman Counties. Part of the contract deliverables included intensity images. These images were shared with the APFO to assist in researching and building the control point database. The images have a ground sample distance of 1.5 feet, are panchromatic, and have good contrast so that selecting control points is relatively straightforward.

The methodology for selecting a point involves choosing a location that would be photo-identifiable on a 1-meter resolution image (the current NAIP resolution). The point must also have attribute information as well as support data, just as the points in the control point database do. In the case of the Oregon data, all of the above are known. Using ArcGIS 9.3, a control point shapefile was created. Next, a point was digitized on a photo-identifiable feature and the following attributes were populated: latitude and longitude in decimal degrees, UTM zone, date of collection/digitization, accuracy, point description, horizontal datum, elevation, and an identifier of who collected the point. The elevation (z value) can be determined by loading the associated LiDAR point shapefile and checking the elevation in the attribute table. The points are dense enough (9.4 per square meter) that an accurate value can be determined. The point was digitized at a scale of 1:1000. This scale was used, as it allowed for the proper amount of detail in selecting a location (figure 4).

The other option for deriving control points is through automatic extraction. It seems there are several methodologies for automatic derivation of points from intensity images. Many of them include identifying centroids of homogenous areas such as rooftops. However, the accuracy of some automated extraction programs is questionable; in some opinions, the technology has yet to be perfected.

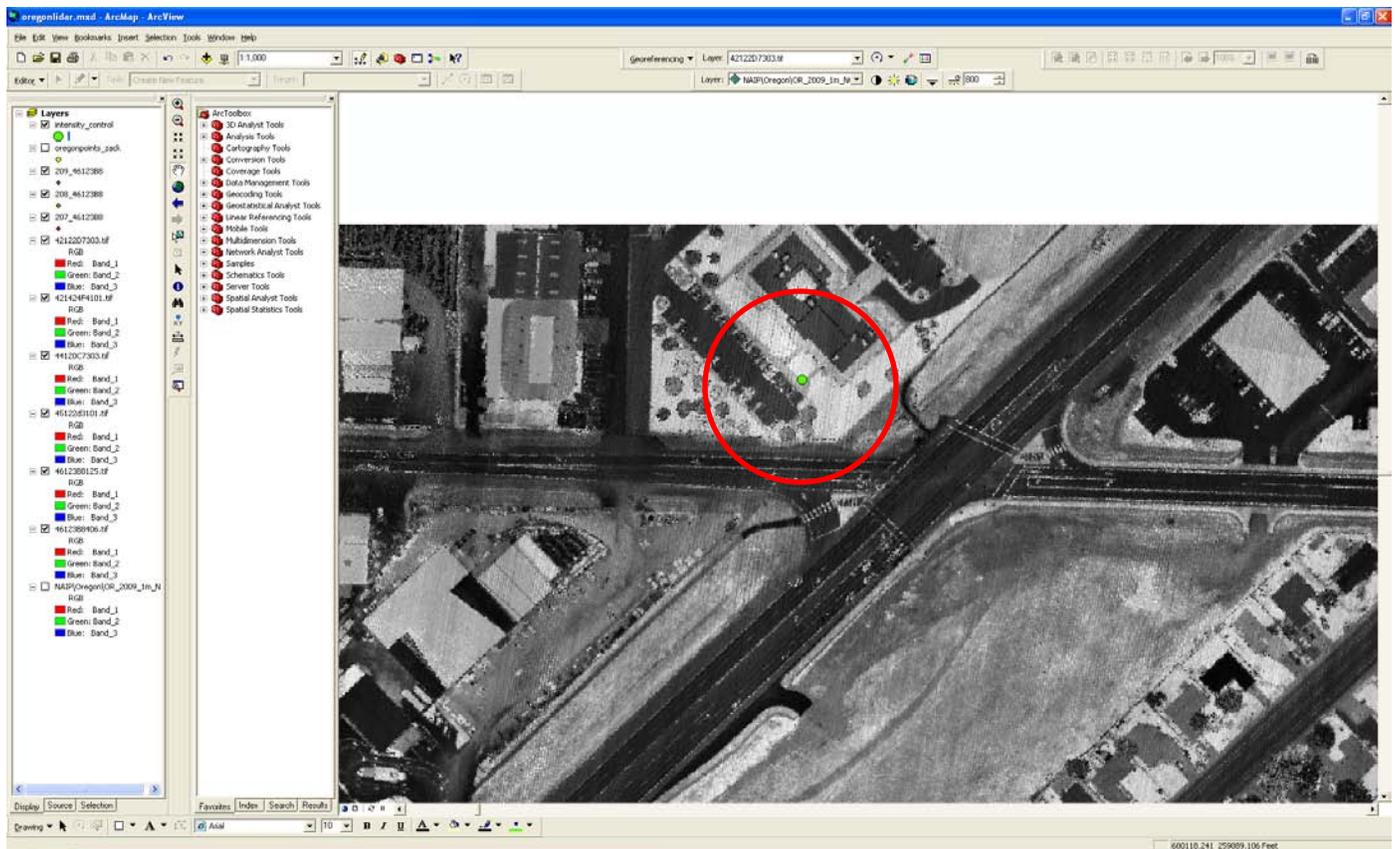


Figure 4: Digitizing the control point

It is also important to check the horizontal accuracy, as tested, of the intensity images. In this case, the points digitized on the images will be tested against known points from the control point database. Ten points were selected from the database. The objective was to digitize those same ten points on the intensity images based on the point description and then output some statistics (Note: Due to the fact that there are only ten check points for the intensity images, no map accuracy standards are being applied here). The idea was to determine if we can be confident that the intensity images are accurate enough to use in a process for deriving control points that meet our horizontal inspection requirements.

Five different individuals digitized the points at a scale of 1:1000. The graphs in figures 5, 6, and 7 illustrate the mean, standard deviation, and root mean square error for each set of measurements. Based upon these statistics, it would appear that the intensity images exceed the APFO accuracy requirements for ground control points.

Another element to check is the accuracy of a control point digitized on the intensity images versus the same location on the 2009 NAIP imagery. To check this, five points were digitized (one for each intensity image). The same location was checked on the NAIP imagery. The results in figure 8 indicate that the intensity images are of a high accuracy in relation to the 2009 NAIP imagery. Points derived from LiDAR were tested against ground points from the database and NAIP imagery and in both instances, the results showed that the intensity images meet or exceed current control point accuracy requirements.

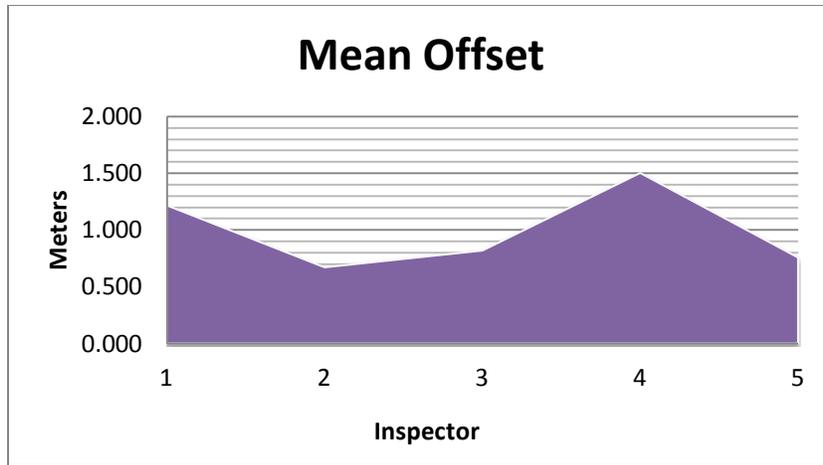


Figure 5: Mean offset from true ground

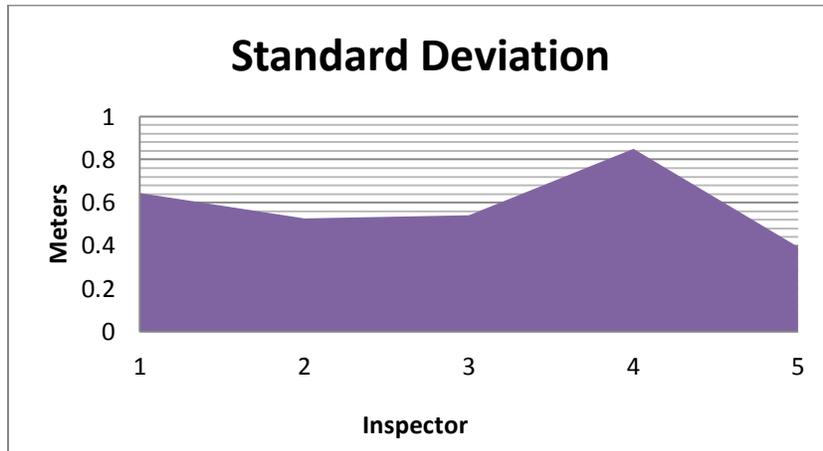


Figure 6: Standard deviations of inspector measurements

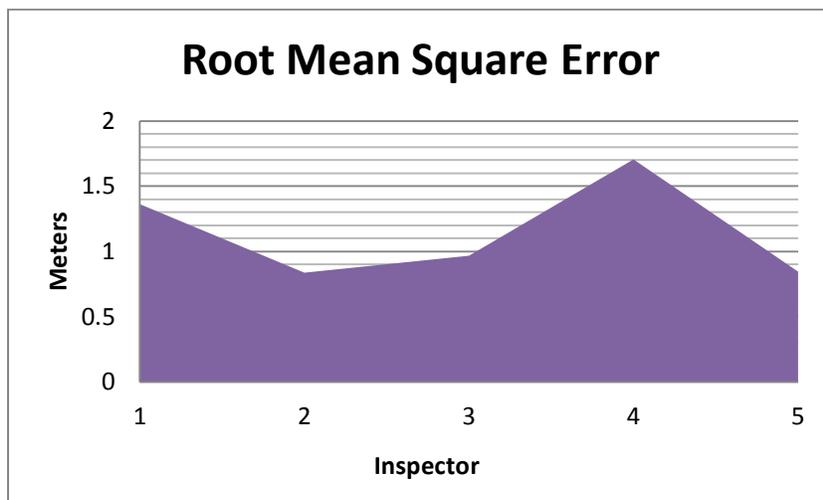


Figure 7: RMSE of inspector measurements

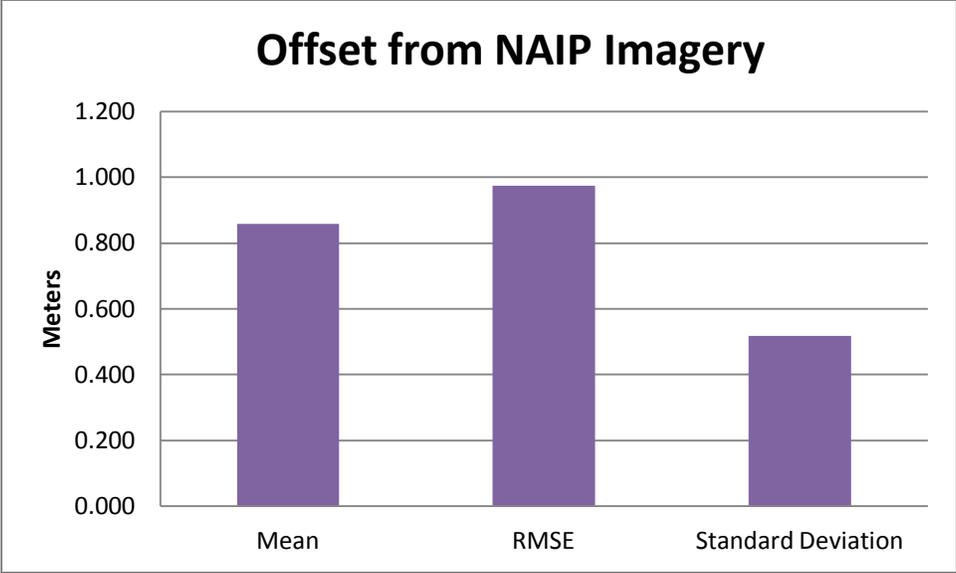


Figure 8: Offset statistics from NAIP imagery

Pros and Cons of Using Control Points from Intensity Images

Certainly, deriving control points from higher resolution sources such as LiDAR intensity images can benefit the control point database. These points can help fill in areas where there are gaps in point coverage. However, there are some issues to consider. As illustrated in the previous section, the LiDAR intensity images meet or exceed the horizontal accuracy requirements of the control point database as well as requirements in the NAIP contract. But, deriving control from other sources (imagery, data points, etc.) is considered a “relative” process. Currently, NAIP imagery is held to an “absolute” accuracy standard so using a relative source for control does not meet this requirement. Although LiDAR data has been around for several years, availability of point clouds and intensity imagery is somewhat limited. So, there may not be data available for areas where control points are needed. APFO – GSB could generate intensity images from point data. There are several software platforms that will accomplish this including ArcGIS 10 and ENVI 4.8. This would require extracting the “bare earth” returns from a LiDAR point cloud and then processing the points into raster images. Creating a point from “scratch” has risks and benefits. An obvious benefit is that areas lacking in control points would now have coverage. But the amount of time to research and modify LiDAR data, output rasters, and finally create a point that is ready for the database could be very time consuming. The cost involved must also be considered. In 2010, APFO purchased control points from CompassData for about 300 to 400 dollars per point. These points met all requirements, were considered “absolute control”, and were database ready. How would the cost compare if an APFO employee went through the whole process of creating a “relative control” point from raw LiDAR data? If the process takes five hours, the cost (based only on approximate employee salary) would be around 200 dollars. The cost is less, but the confidence in the accuracy of the purchased points is higher. It is known that the purchased points were collected with high accuracy survey grade antennae by trained surveyors. Since a point created from LiDAR data is considered relative throughout the whole process, the potential for errors is much greater.

Probably the most important thing to consider about deriving control points from intensity images is the technical know-how and ability of the individual extracting and digitizing the point. The person must be knowledgeable about image interpretation, feature extraction, and be able to digitize a precise location on an image. Any error introduced at this point will be compounded throughout the whole control point process from database input to imagery inspection.

Conclusion

Based on measured accuracy data alone, control points derived from LiDAR would work for the control point database. However, using these points might imply a change to NAIP contract specifications. The contract language would need to be amended to allow for a “relative” accuracy specification and not just “absolute” or conversely, it would need to be disclosed to NAIP Contractors that some inspection check points are derived with relative accuracy methodologies. Use of the points may also cause issues with interpretation of inspection results, unless these derived points are kept separate from absolute points. The attribute tables of the control points would have to be created and standardized to look the same as those found in the current control point database. These tables would also need a field to identify the points as “relative”, “derived”, or something similar. Manually populating the attribute tables would be very time consuming but an automated process could reduce the effort.

Perhaps LiDAR isn’t the only higher accuracy data that control could be derived from. Higher resolution imagery as well as hillshades created from elevation data could be used. The methodology to extract control points from these images would be the same as a LiDAR intensity image.

Currently, there are many issues to consider before adding these points to the database and using them with horizontal accuracy inspection processes. However, it may be a practical alternative for the future. At this stage, a recommendation would be to conduct a pilot project. The project would include selecting an area with little or no control point coverage that has LiDAR data available and then going through the process of extracting a control point from the intensity image, correctly attributing the point, and then loading into the control point database. It would also be worthwhile to extract points through an automated process to determine if this is a viable method. The purpose of the pilot project would be to determine if using LiDAR data as a control point source is a feasible alternative to current methods.

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