U.S. Department
of Transportation
**Federal Aviation
Administration**

# Advisory Circular

**Subject:** Standards for Using Remote Sensing Technologies in Airport Surveys | **Date:** DRAFT | **AC No:** 150/5300-17C
**Initiated by:** AAS-100 | **Change:**



**1. What is the purpose of this AC?**

This Advisory Circular (AC) provides guidance regarding the use of remote sensing technologies in the collection of data describing the physical infrastructure of an airport. This AC describes the acceptable uses and standards for use of different remote sensing technologies in the data collection process.

**2. Who does this Advisory Circular (AC) apply to?**

**a.** This AC applies to airport proponents contracting airport surveying services utilizing remote sensing technologies, such as aerial or satellite imagery or Light Detection and Ranging (LIDAR).

**b.** This AC also provides data providers the standards and recommended practices for using remote sensing technologies in the collection of airport data.

**3. Does this AC cancel any prior ACs?**

This AC cancels AC 150/5300-17B, General Guidance and Specifications for Aeronautical Survey Airport Imagery Acquisition and Submission to the National Geodetic Survey, dated September 29, 2008.

**4. What are the Principal Changes in this Version?**

This is a substantial rewrite of this advisory circular and users should review the entire document. The major changes include reformatting of the document and adding sections regarding the uses and limitations of remote sensing technologies other than aerial imagery for use in collecting airport data.

**5. What is the Application of this AC?**

The Federal Aviation Administration (FAA) recommends the use of the guidance and specifications in this Advisory Circular for the collection and submission of data using remote sensing technologies. In general, use of this AC is not mandatory. However, the use of this AC is mandatory for all projects funded with revenue or federal grant monies used through the

Airport Improvement Program (AIP) and Passenger Facility Charges (PFC) Program. See Grant Assistance No. 34, "Policies, Standards, and Specifications," and PFC Assurance No.9, "Standards and Specifications."

**6. Where do I provide comments or suggestions?**

Direct comments or suggestions regarding this AC to:

Manager, Airport Engineering Division
Federal Aviation Administration
ATTN: AAS-100
800 Independence Avenue, S.W.
Suite 621
Washington, DC 20591

**7. Where can I obtain copies of this AC:**

The FAA Office of Airport Safety and Standards has made this AC available to the public for download through the FAA's Internet home page (www.faa.gov). You can view a list of all ACs at http://www.faa.gov/regulations_policies/advisory_circulars/ . You can view the other FAA regulatory guidance at http://www.faa.gov/regulations_policies/faa_regulations/.

Michael J. O'Donnell
Director, Office of Airport Safety and Standards

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# CHAPTER 1. REMOTE SENSING TECHNOLOGIES

## 1.1 What are the acceptable remote sensing technologies for use airport surveys?

There are three basic technologies in wide use today for the collection of data on and surrounding the airport. Each of these technologies has advantages and disadvantages to its use. The airport proponent should understand the capabilities of each technology including its benefits and limitations before deciding which technology or combination of technologies is appropriate for their project.

**a.** Aerial imagery is the most common technology being used in the planning, design, construction, and analysis activities of an airport. In collecting aerial imagery an aircraft fitted with a camera (film or digital) flies a series of flight lines over the airport and surrounding area to capture images. Aerial imagery is a passive collection system since it relies on capturing the radiation (generally from the Sun) reflected off an object and captured by the camera.

**b.** Light Detection and Ranging (LIDAR) scanning technology is a rapidly evolving field of active source remote sensing providing accurate spatial coordinates of individual points. The LIDAR systems calculate the spatial coordinate of an object using three variables. First the system measures the reflected energy of a laser pulse, it also uses the time of flight for each pulse, and when necessary corrects the data for instrument platform motion to generate a geospatially referenced point cloud representation of the objects within its view. Originally developed for battlefield detection of enemy targets, LIDAR scanners are now in use for a variety of survey tasks and fall into four principle categories:

(1) Ground Based LIDAR (GBL), which is generally used for measuring atmospheric composition;

(2) Airborne LIDAR Mapping (ALM), also known as Airborne Terrestrial LIDAR mapping (ATLM);

(3) Mobile Compensated LIDAR Mapping (MCLM);and

(4) Terrestrial LIDAR Mapping (TLM) sometimes referred to as Ground Based LIDAR Scanning (GBLS or GBLM).

The use of the acronym GBLS and GBLM can create confusion between GBL and systems used for survey mapping (GBLS or GBLM). Within this document we refer to these systems using the acronym TLM to ensure clarity.

The only systems allowable for use in the collection of airport data are those classified in paragraph 1.1.b.

**c.** Satellite imagery uses the same basic concept as aerial imagery except the camera platform is a satellite in space. Currently, the use of satellite imagery to collect airport data is not an approved method, however, the FAA continues to research and identify new uses and standards regarding satellite imagery.

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# CHAPTER 2. REMOTE SENSING PROJECT PLANNING

## 2.1 What are the remote sensing plan requirements?

All projects incorporating the use of remote sensing technologies require the submission of a plan outlining how the data provider proposes to complete the data acquisition.

**a. General Project Information**. The data provider must submit a remote sensing plan to the FAA through Airports GIS (http://airports-gis.faa.gov) for review and approval prior to beginning of data acquisition. Provide the plan in a non-editable format such as Adobe Portable Document Format (PDF)™, detailing the following information:

**b. Airport Name.**

(1) Airport Identifier

(2) Submitting Organization Information to include:

- Name
- Address
- City
- State
- Zip Code
- Telephone Number
- Facsimile Number
- Organization’s Contact Person Name
- E-Mail Address

For purposes of this report, the submitting organization is the Airport authority, proponent or sponsor. If used, identify the consultant collecting the information within the Airports GIS project.

**c. Project Purpose.** Provide a brief statement outlining the purpose of the project. This statement should describe why the airport is undertaking the data acquisition. If the project supports a larger project such as construction activity, indicate this within the project purpose.

**d. Project Boundaries.** Briefly describe project boundaries of the data acquisition project. The description must include details about the surfaces and/or areas the data acquisition will cover such as obstruction identification surfaces (OIS), airport properties and other areas controlling the extent of the acquisition. Should the imagery acquisition include OIS, specify the runways for evaluation. In addition to the description, provide an active KML file or GeoReferenced PDF of the project areas (see Figure 2-1).

**e. Project Parameters.** Briefly describe the proposed details of the data acquisition including at a minimum the following items:

(1) Aerial Imagery Missions. Describe the digital image resolution, horizontal and vertical accuracies values the provider anticipates to achieve in the data collection. Provide the accuracies in Feet determined using Root Mean Square Error (RMSE). The values must comply with values in Table 3-1, Map Accuracies as a Function of Photo/Map Scale in this AC. If using multiple flight missions at different flying heights for the imagery acquisition; provide details for each flight mission. Flight mission details should include at a minimum the following information: flying height (AGL), overlap percentage, side lap percentage, number of flight lines, number of total exposures, cameral film type (if using film), and flight mission date range and sun angle range.

(2) LIDAR Data Acquisition Missions. In addition to the other requirements, projects using ALTM technologies will define the data collection parameters and include an active KML file or Georeferenced PDF of the flight lines (see Figure 2-1). The plan will identify the flying height, speed over ground, scan angle, Pulse Repetition Frequency (PRF), and overall density of the horizontal and vertical point spacing for the data acquisition.

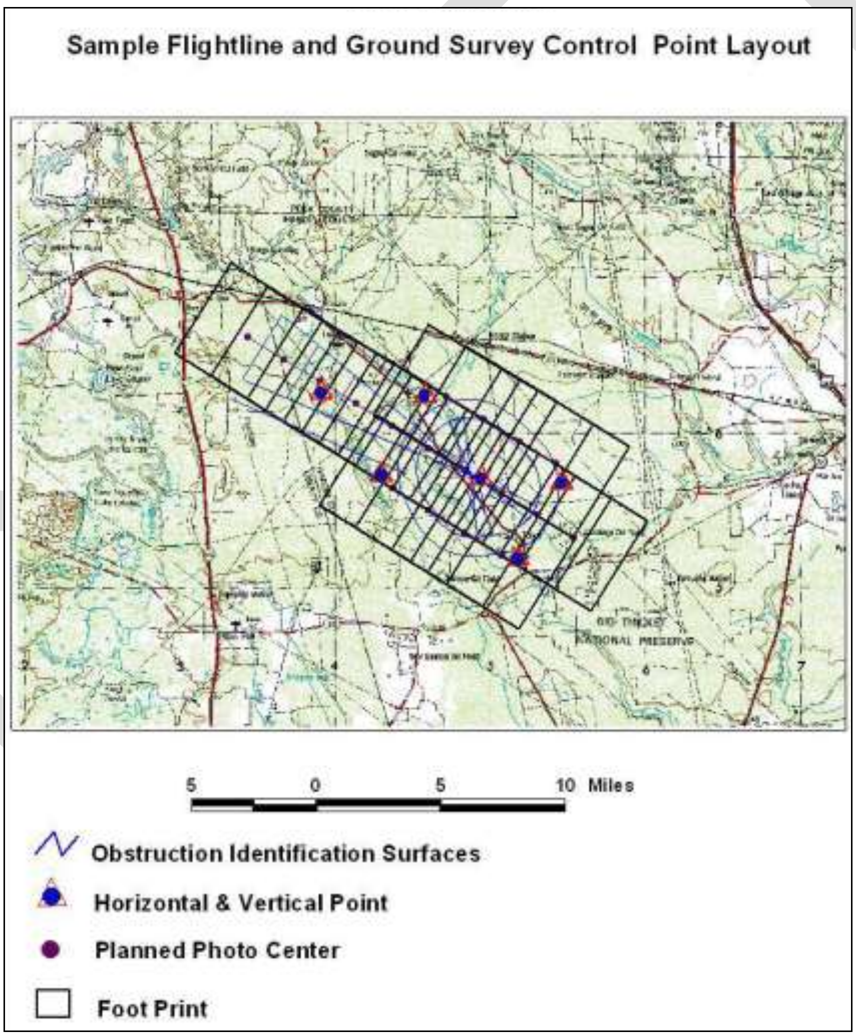


**Figure 2-1 illustrates a combined flight line and supporting ground control network for the project.**

**f.** In addition to the other requirements, data providers proposing to MCLM technologies, will define how they will verify the satellite availability during the times of data acquisition. MLCM projects require a minimum of five satellites in view for the Global Navigation Satellite System (GNSS) Control Stations and the GNSS unit in the MCLM system. In the plan, identify the predicted Position Dilution of Precision (PDOP) for the times of data acquisition. Prior to performing data acquisition, data provider should visit the site to determine the best time(s) for data acquisition to minimize excessive “artifacts” in the data from surrounding traffic or other factors, and to identify obstructions with the potential to cause GNSS signal loss. Identify areas in the project with the potential to have poor satellite visibility and develop a plan to minimize the effect on the data, such as a network densification of transformation points and the inclusion of additional confidence measurement points. For MCLM collections, the predicted and actual PDOP during acquisition must be a value of five or less.

**g.** In addition to the other requirements, data providers proposing to incorporate TLM technologies should perform a reconnaissance of the site(s) to identify and document potential data collection stations. Document the proposed sites using digital photographs. The photographs will include the proposed target and will have a caption electronically added to the photograph. TLM systems capture features in great detail and can detect change on at centimeter levels and in some cases millimeter levels; however, achieving these levels of accuracy require multiple scanner setups (See Figure 2-2). Prior to survey execution, plan station selections for the entire survey area demonstrating capture of the features of interest. Ideally, also determine and document survey control and evaluation locations during reconnaissance. Plan to locate survey targets in areas of scan-arc overlap realizing the actual field conditions may require alternative locations for both scanner and target setup. Data providers should work with local airport authorities to determine the times of day when traffic would have minimum impact on data quality. Plan to scan high traffic areas during times with the lightest traffic. Identify areas of vegetation and or poor visibility and provide specific detail on how and when to acquire data from these areas.

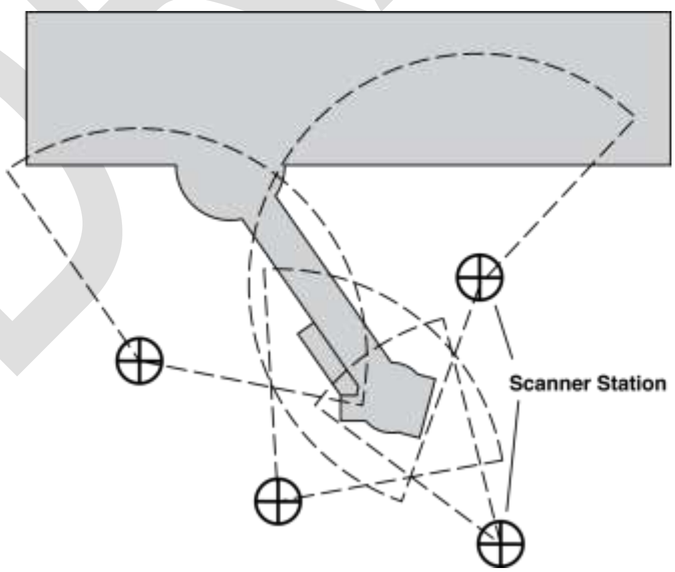


**Figure 2-2 illustrates the scanner and target locations for collection of a passenger loading bridge feature.**

Figure 2-2 illustrates a schematic of an airport terminal feature (passenger loading bridge) showing the potential numbers of stations necessary to fully capture the plan view outline of the feature. The dashed polygons in Figure 2-2 depict the region(s) of capture available from each particular station.

(1) Satellite Imagery Acquisitions - Reserved for later implementation

**h. Remote Sensing Equipment.** In this section provide a brief description of the remote sensing equipment the data provider plans to utilize during the project. At a minimum this should include:

(1) For projects incorporating aerial imagery technologies include the:

(a) type of acquisition camera/sensor (make/model),

(b) focal length of proposed camera,

(c) serial number,

(d) Area-weighted average resolution (AWAR) value and calibration date.

(e) The data provider must provide the appropriate Calibration Certificate for all equipment they plan to use in the project. The date of the calibration certificate must be within 3 years of the estimated completion of the data collection. If using a digital camera, provide the calibration report and/or information regarding the manufacturer's recommended equivalent procedure. If providing a manufacturer's recommended procedure, include a Statement of Compliance on company letterhead. The statement of compliance will certify completion of the manufacturer's recommended procedure at the recommended intervals, it will identify the date the procedure was last accomplished before the imagery was flown, and be signed by an authorized representative of the company submitting the Statement of Compliance.

(f) The plan must contain detailed information on how imagery from these sensors will be geo-referenced, the collection bands used, and proposed imagery format.

(g) When using a film based camera, provide the name and model number of the photogrammetric scanner the data provider proposes to use in creating digital images.

(2) For projects incorporating LIDAR technologies include:

(a) The make(s), model(s), serial number(s), and any applicable software version numbers for all equipment the data provider proposes to use in data acquisition.

(b) Before and after collecting the data, ensure the calibration of all equipment in the system according to the manufacturer's specifications. Refer to paragraph 5.5 for system calibration requirements.

(c) There is no standard format for the calibration reports. However, the calibration reports must contain, at a minimum, the following information:

(i) The date the calibration was performed.

(ii) The name of the person, company, or organization responsible for performing the calibration.

(iii) The methods used to perform the calibration.

(iv) The final calibration parameters or corrections determined through the calibration procedures.

(v) A discussion of the results.

(d) Sensor Maintenance – Provide maintenance history of the sensor to be used for acquiring LIDAR.

(3) Reserved for later implementation of Satellite Imagery requirements

**i. Control Point Requirements.**

(1) All remote sensing projects require the use of some type of survey control to register or georeference the data the National Spatial Reference System (NSRS). If airborne GPS procedures are integrated into the flight mission make sure to reference this in the Remote sensing Plan. In this section of the plan, describe the ground control network proposal including characteristics (e.g. panel point, photo identifiable, et cetera), locations, and expected accuracy of measurements in horizontal and vertical axis (stated as accuracy RMSE in feet).

(2) The data provider must develop and provide a Station Location and Visibility Diagram for each control point using the form available in the Surveyors section of the Airports GIS website at http://airports-gis.faa.gov. Include on the form a sketch of the area surrounding the control point.

(3) Take digital photos of the station as prepared to support the data acquisition (See Figure 2-4). Electronically add to the photo a caption to uniquely identify it. Include the filename(s) of the digital image(s) for the station in the sketch section of the appropriate Station Location and Visibility form.

(4) Include an active KML file or GeoReferenced PDF file showing control points supporting the data acquisition for the project area (See Figure 2-1).

(5) The number and placement of the control points must be sufficient to geo-reference the imagery within the accuracy requirement necessary to meet the purpose of the project. The ideal type of point for control identification is one providing a very small, recognizable, and symmetrical photographic image with distinct boundary of a relatively high to a lower contrast. Some examples of “well defined” control points are:

(a) A point at well-defined junctions of intersecting features such as sidewalks, abutments, and roads

(b) Corner points of any clear, well–defined feature such as a parking lot, a tennis court, or a road intersection

(c) An easily identifiable pre-marked or paneled point on the imagery


**Figure 2-3 shows a sample digital photograph of an imagery control point with the antenna located over the point. Note the caption has been added to the photo to aid in identification of the point.**

(6) Data providers proposing to use TLM scanner systems to scan airports must provide a data sample demonstrating the reflective properties of targets they are proposing to use in the survey. There are basically two types of LIDAR targets: object targets; and reflective targets. Object targets are objects of known size; commercially the most common type is a plastic sphere (see Figure 2-4). The construction of cylindrical targets using reflective tape applied to pipe to construct a registration cross is another appropriate target. Once captured by the scanner system, the point cloud data for the target is fit to the appropriate geometry and the quality of the fit is a measure of the accuracy of the target at a particular range.

**Figure 2-4 is an image of a typical shape target used in LIDAR surveys. The material is made of a durable, rough finish, solid plastic sphere that is machined into a 6 inch sphere and mounting bolt for attaching it to a standard 5/8" survey tripod.**

(7) Reflective targets are commercially available for most systems. These targets two dimensional, come in a variety of sizes, and are constructed of a reflective material and are applied directly to a feature (See Figure 2-5). Not all reflective sheet targets are ideal for some systems. Standard sheet targets commonly used for laser theodolites may reflect too strongly resulting in a saturated reading by the scanner system (See Figure 2-6). Using an inappropriate target results in a bright halo defined by the edges of the target and loss of data at the target center, which makes it less than ideal for precise georeferencing of the point cloud data set.

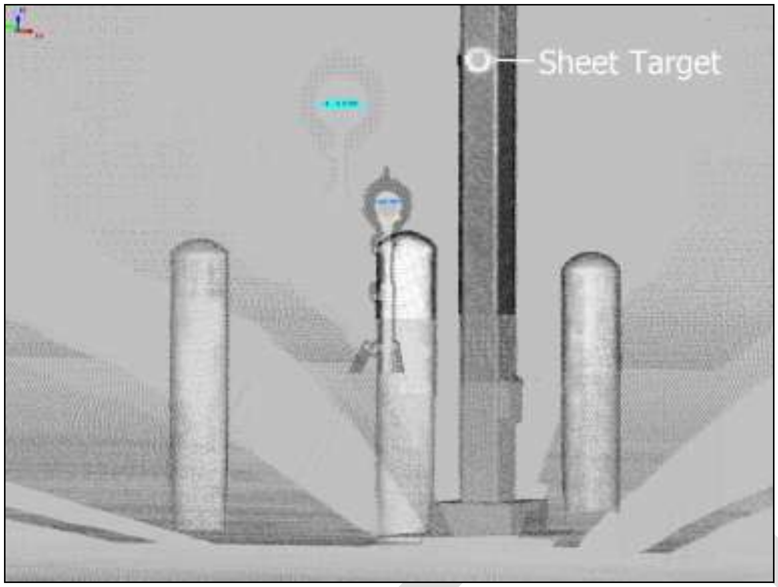


**Figure 2-5 shows the LIDAR response of highly reflective sheet target mounted to the side of a light post.**

(8) Data providers must demonstrate the both types are reflective to the scanner of choice. Many manufactures provide some type of LIDAR target but the use of any object of regular, known dimensions is acceptable as long as it is reflective to the wavelength of laser. Lasers in the 900 or 1500 nm wavelength (near IR) will reflect accurately off of any material that is light in color, non-polished, non-hydrated material.

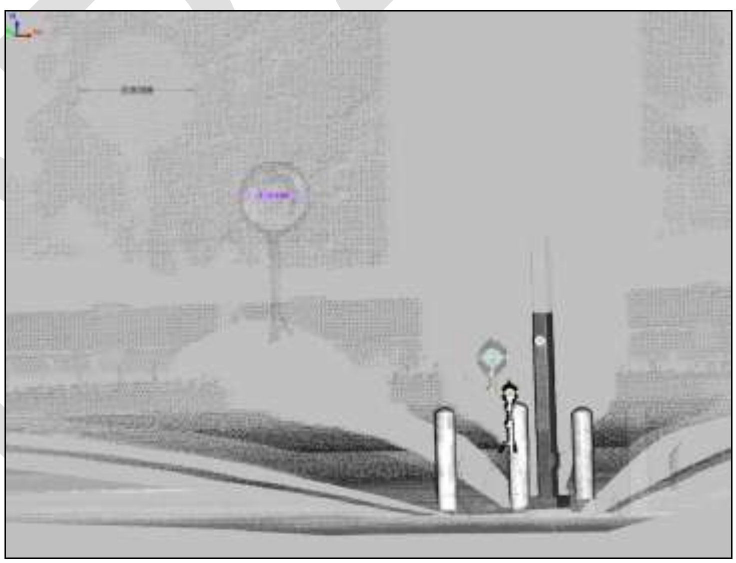

**Figure 2-6 illustrates the potential data shadowing if a traditional survey prime is used as a LIDAR target.**

(9) Do not use surveying prisms as LIDAR targets. The orthogonal mirror geometry will produce a measurement error for any incident beam that does not strike the exact center of

the target. Secondly, the highly reflective target material will capture any beam that overlaps the target producing data shadow behind the target that becomes larger with beam divergence (See Figure 2-6).

(10) Provide an ASCII text file of the final imagery control point values identifying any changes from the imagery plan (as illustrated in Table 2-1). This section should only include the coordinate values (easting, northing, elevation) for the photo control.

**Table 2-1 illustrates an ASCII Control Point file ready for submission**

Imagery Control Point Coordinates—Sample

Airport Name: ______________________________

Coordinate System: ______________________________

UTM Zone: ______________________________
(The state plane coordinate system in which the Airport Reference Point is located may also be used.)

Reference Ellipsoid: ______________________________

Horizontal and Vertical Datum: ______________________________

All heights are in Feet.

| Station Name | Northing | Easting | Orthometric Height | Ellipsoidal Height |
|---|---|---|---|---|
| P01 | 2086849.62 | 3579322.68 | 115.48 | 83.34 |
| P02 | 2086905.37 | 3583818.97 | 78.47 | 46.29 |
| P03 | 2092134.98 | 3584776.85 | 93.59 | 61.45 |
| P04 | 2093245.00 | 3586869.35 | 97.09 | 64.94 |
| P05 | 2089958.84 | 3591583.70 | 88.78 | 56.53 |
| P06 | 2084575.11 | 3596417.02 | 51.81 | 19.39 |
| P07 | 2080281.03 | 3598531.32 | 12.47 | -20.02 |
| P08 | 2075655.30 | 3602180.66 | 3.04 | -29.52 |
| P09 | 2075499.76 | 3599408.29 | 11.76 | -20.77 |

(11) Check Points. All technologies require the data provider provide additional control point locations for use as "check points". The purpose of the check point when using remote sensing technologies is to provide an additional means of verifying the georeferencing of the data. In some cases, check points provide network densification. In addition to control points, collect and provide additional check points within the project area. The check points are

utilized for independent check of accuracies and consist of "OPUS" and "Verification" points. Utilize the NGS Online Positioning User Service (OPUS) to determine point positions. Do not use these check points as part of georeferencing solution for the data. Submit a copy of the OPUS and GPS solution for each check point.

(a) For aerial imagery technologies, provide at least five check points within the project area. Provide a separate table describing the checkpoints similar to the points you use to georeference the imagery (see Table 3-1).

(b) For LIDAR data projects

(i) ALTM technologies require the use of a field test apparatus

(A) Construct the Field/Test of the following materials and methods:

- A base plate or tube approximately 10' in length
- Two (2) 6" diameter sections of PVC pipe, 8' in length, (1) black-color, (1) white-color
- Two (2) 4" diameter sections of PVC pipe, 8' in length, (1) black-color, (1) white-color
- Two (2) 2" diameter sections of PVC pipe, 8' in length, (1) black-color, (1) white-color
- Mount all the PVC sections vertically to the base plate/support so they are as plumb as possible. Equally space the sections across the base plate. The base plate must have two marks, one at each end, to geographically locate the test apparatus once installed in the survey area.

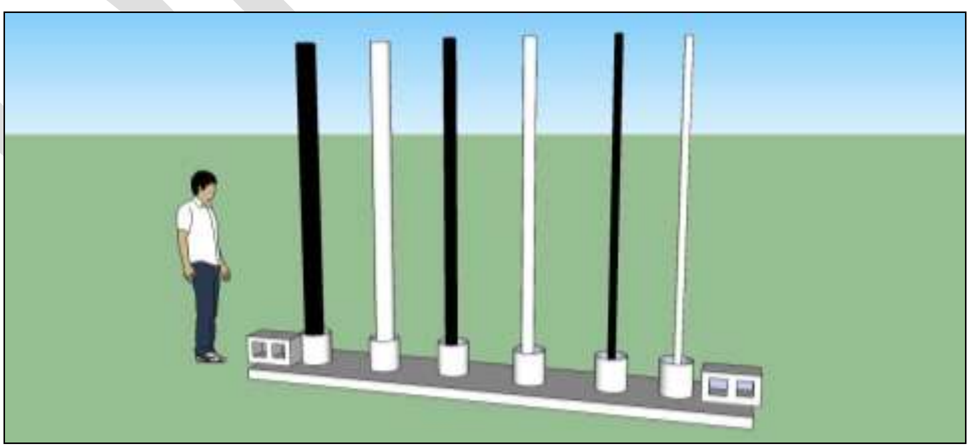

**Figure 2-7 is an example of the Field/Test Apparatus deployed in survey area, stabilized by supports and weights (from NOAA 2009).**

- Using an appropriate GPS Survey grade receiver, collect the position of each end of the support base and process the information through the NGS OPUS to derive the geographic position of each end of the support.

(B) Field/Test Apparatus Placement. To the extent practical, locate the test device in a safe, flat (i.e., level terrain or surface), open area, within a normal section of the survey area. Support the structure if necessary by sand bags or other means so the device will remain erect and stable in windy conditions and so it is not prone to be toppled by passers-by, et cetera.

(C) Flight Regime. The data provider must use the standard mission parameters planned for the survey. Do not collect extra data of the test apparatus location, and do not use any special maneuvers or flight lines to enhance or "densify" data distribution on the test object.

(D) Field/Test Apparatus data analysis. Provide the results to the government (including the OPUS results for the positioning of the end points) for analysis of the test data to determine of the following:

- The number and intensity of LIDAR returns from each vertical component of the device
- The vertical point spacing/density
- The differences between the known top elevations of the vertical components of the device and the elevations determined from the LIDAR data
- The ability to resolve each vertical component

**j.** For MCLM technologies incorporate targets occupying known horizontal and vertical control in MCLM surveys to serve as known local transformation points for point cloud adjustment and validation points for QA/QC. Bracket the scanned area on both sides of project area with scan control (local transformation) points at a maximum of 1500-foot stationing intervals. Validation points should be on both sides of the scanned area, at centerline stationing intervals not exceeding 500 feet for Type A MCLM surveys. Type B MCLM control and validation points should be placed at a maximum of 2400-foot and 800 foot stationing intervals respectively. Targets should be located as close to the MCLM vehicle path possible without compromising safety. The MCLM vehicle operator(s) should adjust the vehicle speed at the target area so that the target(s) will be scanned at sufficient density to ensure good target recognition.

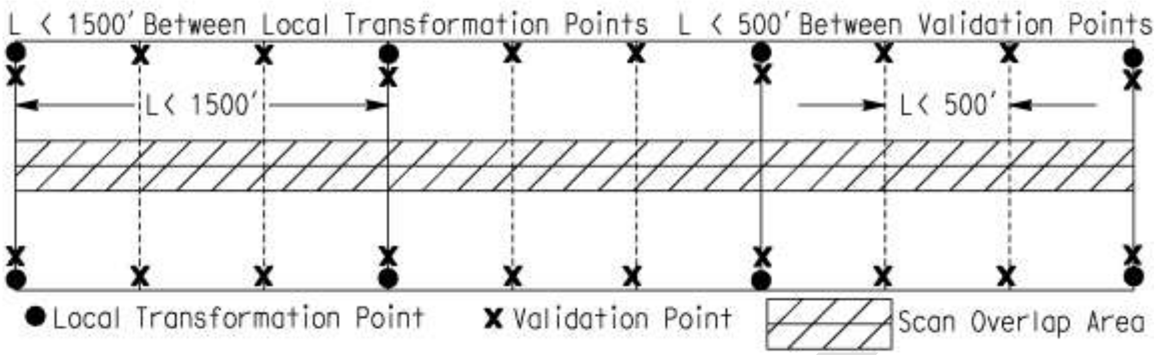


**Figure 2-8 depicts the Typical MCLM Type A Local Transformation and Validation Point Layout**

**k.** For TLM technologies locate control points prior to the scanning campaign. Because the acquisition geometry of TLM scanner systems is radial, it is necessary to establish control points lying within regions of overlap between scanner stations and position reflectors to the geometry (See Figure 2-9). The scanner stations can also be used as part of the survey control by either replacing the scanner head with a survey target or collecting the position of the station using a total station or by using a high-quality GPS solution for the scanner station. Some TLM systems claim to have internal GPS antenna with as low as 1.5 cm resolution/precision. It should be noted that this is not possible without a RTK GPS base station solution or similar differential GPS processing solution.

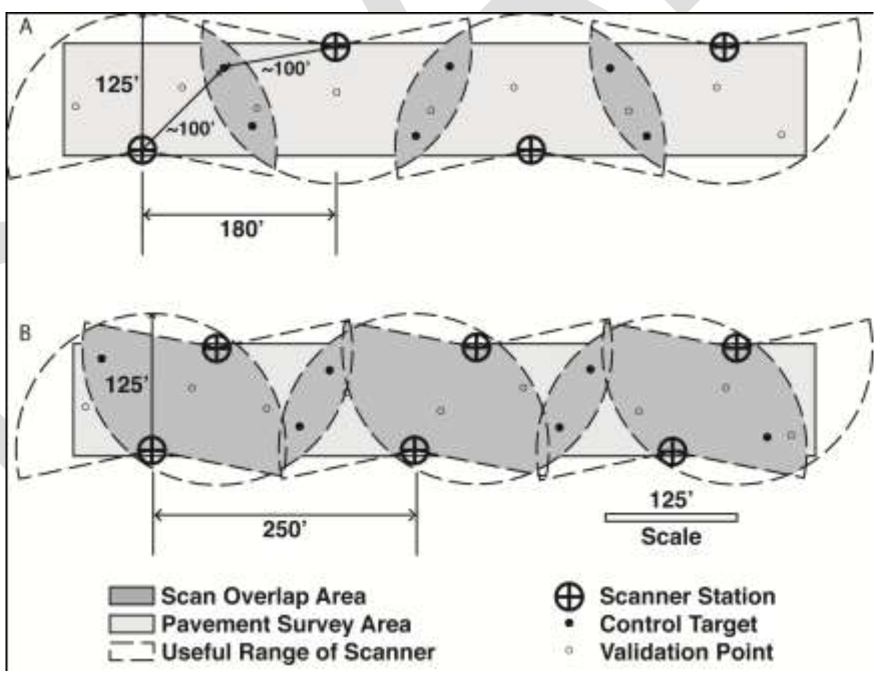


**Figure 2-9 illustrates the scanner setup locations, target locations, validation point locations, areas of overlap and usable scanner range.**

Figure 2-9A depicts a low density pavement survey plan requiring 0.00125° step size at 125 feet. Some scanners have dynamic spacing that is uniform at any range, which greatly reduces data acquisition time and number of points collected. Figure 2-9B depicts a high station density pavement survey plan requiring 0.0025° step size at 125 feet. Regions of low no overlap should have adequate spacing because these areas are within 75' of the scanner station. More setups are required, but scanning time is cut in half. (Modified from Caltrans 2010 source.)

**l. Georeferencing Requirements.** In this section of the plan, the data provider must describe the techniques and tools (including software and version number) they plan to use in georeferencing the data. This description must include a statement of expected accuracies and associated tolerances derived from the proposed georeferencing methodology.

**m. Remote Sensing Schedule.** The data provider must provide a generalized schedule identifying anticipated acquisition dates and times, delivery of required data, orthoimagery and other information to the government.

**n. Quality Assurance and Quality Control.** The data provider must describe their methodologies for ensuring the quality of the data and all associated information such as forms, digital photos etc. The data provider should discuss their processes and procedures for ensuring the checked, complete, reliable, and meets the accuracy requirements (including error analysis) for the type of project.

## 2.2 How do I document the location of a proposed runway extension in aerial imagery?

Locate the design runway end location using GPS methodologies then construct a standard photogrammetric panel at the location and document it as any other control point. Post-process the location using NGS OPUS and provide and provide a separate ASCII Control Point file containing the appropriate information. Ensure the header information of the ASCII file clearly identifies the information as pertaining to the proposed runway end location.

## 2.3 What are the requirements for horizontal and vertical ties to the NSRS?

**a.** Tie all imagery control points to the National Spatial Reference System (NSRS) horizontally using the North American Datum of 1983 (NAD 83) and vertically using the North American Vertical Datum of 1988 (NAVD 88). In Alaska and other areas outside the continental United States where NAVD 88 benchmarks are not available, contact the National Geodetic Survey (NGS) for further guidance.

**b.** The required horizontal accuracy requirement for image photo control points is 0.3 meters (1 foot) relative to the NSRS, while the required orthometric accuracy must be 0.3 meters (1 foot) relative to the NSRS.

## 2.4 Can I use LIDAR to perform an obstruction analysis?

As a fairly recent and rapidly evolving technology, the FAA limits the use of LIDAR in collecting airport data and requires certain additional requirements and supporting documentation. Data providers may use LIDAR technologies (specifically ALTM) in the capture of data <u>*supporting*</u> an obstruction analysis. The FAA is continuing its research into the use of LIDAR in airport data collection and will update these standards as appropriate. LIDAR mapping has the capacity to provide for the collection of many of the airport data elements in AC

150/5300-18. However, any single technology will not capture all feature classes. Key factors include the view angle and the positional accuracy requirements for individual features (e.g., ATLM can detect with sub-meter precision objects viewed from the nadir position, vertical surfaces or objects smaller than 12-16 inches cannot be adequately captured) and will require supplemental data collection using a separate sensor or other surveying technologies. A large range of useful data products from any LIDAR data acquisition require post-processing interpretation of the data. Any automated feature class recognition software must be approved by the government prior to use. The data provider must check the results for accuracy by comparison to digital photography or spot checking results at the survey site or by both. Additional information regarding the use of LIDAR in obstruction analysis is found in paragraph 5.9.b.

### 2.5 What are the data delivery requirements for remote sensing projects?

Deliver all data on removable media such as USB hard drives clearly labeled with the following information; Project name, Collection date(s), Data Provider's name, and disk contents. Deliver all project removable media to the government at the following address.

FAA Airport Safety and Standards Contract Support Team
Innovative Solutions International
1201 Maryland Avenue S.W.
Suite 510
Washington, D.C. 20024

# CHAPTER 3. AERIAL IMAGERY SPECIFIC STANDARDS AND RECOMMENDED PRACTICES

## 3.1 What is the timeframe for imagery acquisition?

Acquire imagery for use in planning, design, construction, or analysis activities within 6 months prior to its intended date of use. This ensures the imagery accurately depicts the environment on and surrounding the airport. The use of imagery collected more than 6 months but less than 18 months of its intended use is acceptable as long as a means to identify and document changes occurring within the area of coverage since the time of collection is provided.

## 3.2 Do we capture the imagery in a leaf on or leaf off condition?

The determining factor of leaf on or leaf off condition in the acquisition of the imagery is a function of the project. If the project requires an Airport Airspace Analysis then full leaf on conditions are required. If the purpose of the imagery supports a project (such as an engineering or planning project) not requiring Airport Airspace Analysis, then the acquisition in a leaf off condition is acceptable. The data provider will identify in the remote sensing plan if the imagery collection is leaf on or leaf off. This may require flights in both conditions to meet the project objective, however, in most cases flying leaf on is the preferred condition.

## 3.3 What are the equipment and supplies requirements when using aerial imagery technologies?

**a. Frame (Film-based) Cameras 230 mm-Format.** When utilizing a single lens metric camera, it must provide an equivalent resolution to or exceeding the capabilities of a Wild RC 30 or Z/I Imaging RMK-TOP 15, with forward motion compensation. The lens should have an area weighted average resolution (AWAR) of at least 85.0 lines per millimeter however; an AWAR of 100 is preferred.

**b. Aerial Film.** Use High-resolution color negative aerial film to obtain aerial imagery. Film types such as Kodak 2444 or AGFA Aviphot X-100 are preferred. The low-contrast target resolution of color negative emulsions must be rated at greater than or equal to 80 line pairs per millimeter (lp/mm). Emulsion and filter combinations selected must be sensitive to and record on the film the green, yellow, orange, and red hues of the tree leaf canopy.

**c. Photogrammetric Scanner.** Convert aerial film to raster imagery on photogrammetric scanners with high geometric accuracy capable of producing scan pixel size of 15 microns or less. The data provider will identify the type of scanner they intend to use in the remote sensing plan.

**d. Large-format Frame Digital Cameras.** Digital cameras with high quality frame imagery such as the Zeiss DMC, Ultracam, DDS, or equivalent system are permissible for use and require approval on a case by case basis. The sensor must be a geometrically stable and have a calibrated system suitable to use for high-accuracy photogrammetric mapping. The sensor must provide a high enough resolution and have a large Field of View (FOV) to meet the project requirements. The sensor must record in the red, green, and blue (RGB) spectral bands and produce an image replicating natural color. If the sensor records in the near IR band, provide this information also.

**e. Flight Planning**

(1) Flying Height - The target flying height must be to ensure it meets the positional accuracy requirements necessary for the project. The flying height must provide for the appropriate level of image resolution necessary to accurately define the smallest sized features to their appropriate accuracy requirement. For projects extracting features within the airport boundary it is recommended projects utilize a second lower flight height to allow for capture of small sized objects such as runway lights. Proposed flying heights must not exceed 12,000 feet above ground level (AGL) for film-based systems utilizing a 6-inch focal length camera. Choose the flying height for a digital camera system to produce an image resolution and quality greater than or equal to the resolution and quality obtainable from filmed based systems. Flying at lower altitudes is highly recommended to increase the usability of the imagery for other purposes; such as mapping, engineering and planning activities of the airport. The flying height variation must not exceed 2 percent below or 5 percent above the target level identified in the remote sensing plan.

**Table 3-1 identifies recommended and maximum flying scales for film based systems at different pixel resolutions.**

| **Map Accuracies as a Function of Photo/Map Scale** | | | | | | |
|---|---|---|---|---|---|---|
| | **Recommended** | **Maximum** | **Recommended** | **Maximum** | **Recommended** | **Maximum** |
| Pixel | .25’ | .25’ | .5’ | .5’ | 1’ | 1’ |
| Film Scale | 1"=300’ | 1"=440’ | 1"=600’ | 1"=880’ | 1"=1200’ | 1"=1720’ |
| Flying | 1800’ | 2700’ | 3600’ | 5400’ | 7200’ | 10800’ |
| Scan | 21 | 14 | 21 | 14 | 21 | 14 |

(2) **Image Overlap and Sidelap** - For frame imaging systems, the forward overlap must average 60 percent between consecutive exposures, while forward overlap must not be greater than 68 percent or less than 55 percent in any pair of consecutive images. Plan the flight to minimize imagery sidelap. Planning for the appropriate sidelap normally equates to 50 percent overlap for a film-based system with the acceptable range being 30 to 60 percent. A sidelap of 50 percent is recommended to ensure objects are seen in stereo from multiple views. 50 percent side lap is critical in forested areas.

(3) **Flight Line Navigation** - All flight lines should be continuous and not be broken or patched. If a line requires a second flight, it must have the original flight line number.

(4) **Tilt -** Ensure the tilt (departure from the vertical) of the camera is kept to a minimum. Tilt must not exceed ± 3° for any photographic frame. The average tilt for the entire project must not exceed ± 1 degree.

(5) **Crab -** Ensure the imaging system is compensates for the crab of the aircraft, with a resultant error not exceeding ± 5 degrees, as measured from the average line of flight with a differential between any two successive exposures not exceeding ± 5 degrees.

## 3.4 What information do I include in the Aerial Photogrammetric Report?

**a.** Include in the Aerial Photogrammetric (AP) acquisition report, the raw stereo imagery (and accompanying set up files) and supporting documentation. Submit the raw stereo imagery and AP acquisition report to the FAA after completing the flight mission but prior to the delivery of any associated survey data. Provide the AP report and supporting deliverables in the following directory structure.

**b.** Establish the directory structure (see Figure 3-1) so each folder contains pertinent information about each item. Name the root directory using the assigned FAA airport location identifier, for example, BOS AP Acquisition Report for Boston Logan International Airport. Develop and include a table of contents for each submission and store it in the root directory.

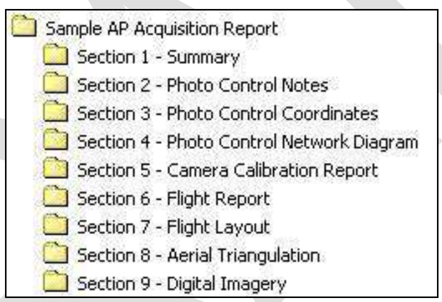


**Figure 3-1 illustrates provides an example directory structure for an AP acquisition project.**

**c.** Upload all sections of the AP Acquisition Report, with the exception of Section 9 – Digital Imagery to the FAA using the Airports GIS web site. Deliver Section 9 – Digital Imagery and associated supporting documentation for review at the following address.

FAA Airport Safety and Standards Contract Support Team
Innovative Solutions International
1201 Maryland Avenue S.W.
Suite 510
Washington, D.C. 20024

**d.** The following sections provide additional information regarding each section.

(1) Summary. Provide a summary of project details and any deviations to the imagery plan content. The data provider should provide any supplemental information they consider useful or explanatory for use by FAA in reviewing the usability of the imagery.

Comments are required when the project is completed differently than identified in the imagery plan due to unusual circumstances or problems, equipment malfunctions, changes to proposed methodologies/equipment or any deviations from these specifications.

(2) Photo Control Notes. Provide image control point and check point photographs (properly labeled and matching the point listing in the ASCII text file supplied), location/visibility sketches and copy of OPUS solution for the five check points not used in the Aerial Triangulation process.

(3) Photo Control Coordinates. Provide an ASCII text file of the final imagery control point values identifying any changes from the remote sensing plan (as illustrated in Table 3-2). This section should only include the coordinate values (easting, northing, elevation) for the photo control and the OPUS 5 check points.

**Table 3-2 depicting a sample ASCII Imagery Control Points File.**

Imagery Control Point Coordinates—Sample

Airport Name: ____________________

Coordinate System: ____________________

UTM Zone: ____________________
(The state plane coordinate system in which the Airport Reference Point is located may also be used.)

Reference Ellipsoid: ____________________

Horizontal and Vertical Datum: ____________________

All heights are in Feet.

| Station Name | Northing | Easting | Orthometric Height | Ellipsoidal Height |
|---|---|---|---|---|
| P01 | 2086849.62 | 3579322.68 | 115.48 | 83.34 |
| P02 | 2086905.37 | 3583818.97 | 78.47 | 46.29 |
| P03 | 2092134.98 | 3584776.85 | 93.59 | 61.45 |
| P04 | 2093245.00 | 3586869.35 | 97.09 | 64.94 |
| P05 | 2089958.84 | 3591583.70 | 88.78 | 56.53 |
| P06 | 2084575.11 | 3596417.02 | 51.81 | 19.39 |
| P07 | 2080281.03 | 3598531.32 | 12.47 | -20.02 |
| P08 | 2075655.30 | 3602180.66 | 3.04 | -29.52 |
| P09 | 2075499.76 | 3599408.29 | 11.76 | -20.77 |

(4) Photo Control Network Diagram. Provide an active KML or GeoPDF depicting all control stations the data used in georeferencing the imagery including information regarding their tie to the NSRS.

(5) Camera Calibration Report. Provide a copy of the camera calibration report for the camera used during the acquisition of the photo mission.

(6) Flight Report. Provide an Imagery Flight Report using the Photographic Flight Report form available at http://airports-gis.faa.gov. Instructions for Completing the Photographic Flight Report for Airport Photography are as follows:

DATE—Film is first loaded into the cassette of Magazine, Print "LOADED" and Date

ROLL NUMBER—Year, Camera System Designator, Film Type (CN = Color Negative), and Sequential Roll Number for that Calendar Year.

EMULSION NUMBER—Taken directly from the film can upon loading.

EXPIRATION DATE—Taken from film can upon loading.

SHEET NUMBER— X of Y sheets = 1 of 4, 2 of 4, etc.

FILM TYPE—Color, Color Negative, etc.

ISO INDEX—Film speed actually used (not EAFS from film can).

FILTER—Wavelength of filter used, in Nanometers.

CASSETTE/MAGAZINE—Feed and take-up cassettes or magazine identification number.

CAMERA/DRIVE UNIT NUMBERS—Camera identification number or lens serial number/drive unit number.

MISSION NUMBER —Aircraft Type (Cessna Citation II).

AIRCRAFT—Aircraft Tail Number (N52RF)

PILOT—Printed Surname.

COPILOT—Printed Surname.

PHOTOGRAPHER—Printed Surname.

DATE and LINE NUMBER—Date of photography (Month, Day, Year), flight line number (30-002, indicating a scale of 1:30,000 and Line No. 2). Add note "NEW DAY" to indicate a date change. Place near the date entry.

GMT/LOCAL—Time (Coordinated Universal Time or GMT) in Hours and Minutes and associated local time.

COMP HEAD/DRIFT—Enter the magnetic heading in degrees/variances in degrees left or right of the path of the aircraft and ground tracking over the planned flight line.

ADD NUMBERS—Enter the first and last frame numbers of the line.

NUMBER OF EXPOSURES—To remain blank.

VISIBILITY—Distance in statute miles out from the aircraft, in the direction of the sun, at which tree crowns are still separately discernable.

CLOUDS—Enter an estimate of cloud-cover from choices at the end of the photographic flight report.

TEMPERATURE—Enter the temperature in degrees Celsius at the time of the photography.

ALTITUDE—Feet above ground level (AGL) over Airports.

VACUUM—Enter vacuum reading from gauge or from camera display panel (600 mmws, or nominally 64 mb standard).

SHUTTER—Enter speed of shutter during line of photography. Enter, if in automatic mode, variances in shutter speeds (450-550).

APERTURE—Enter the actual aperture used. Final adjustment from camera indicator, not base exposure from an automatic light meter.

RHEOSTAT—Enter the rheostat setting as a function of the ISO (“per xxx ISO”).

ENDLAP—Enter the planned percentage of endlap as a whole number (60, 80, etc.).

NUMBER OF BLANKS TO START OF ROLL— "6" is standard.

METER READINGS— Record the automatic light meter readings (4 @ 1000)

CRAB — Provide the crab angle of the aircraft during acquisition

TILT — Provide the camera tilt (departure from vertical) during acquisition

SUN ANGLE — record the sun angle at the time of acquisition

OVERLAP/SIDELAP — Enter the planned percentage of overlap and sidelap as a whole number (60, 80, etc.).

REMARKS—A description of the terrain, local ambient conditions, and remarks concerning abnormalities.

(7) Flight Layout. Provide a Flight Layout diagram showing “actual” flight line length, direction of flight, flight line number, exposure numbers on the flight line and any deviations from original flight mission plan. Provide this as an active KML or GeoPDF file.

(8) Aerial Triangulation. Provide an ASCII file (as in the Table 3 below) containing camera focal length and the X, Y, Z, omega, phi, and kappa of each image. Provide the information in the Universal Transverse Mercator (UTM) or State Plane Coordinate System, NAD-83. Specify the Zone used and include with the submitted file the information identified below.

- Strip Number
- Image Number
- Easting specified in the coordinate system Unit of Measure (UoM) to the hundredth
- Northing specified in UoM to the hundredth
- Orthometric Height specified in UoM to the hundredth
- Omega specified in decimal degrees to six (6) decimal places
- Phi specified in decimal degrees to six (6) decimal places
- Kappa specified in decimal degrees to six (6) decimal places
- Provide Final adjusted Aerial Triangulation report showing RMSE

(9) Digital Imagery. Provide digital stereo imagery (and supporting set up files) of the area of analysis. The extent of aerial imagery coverage depends on the type of survey the contractor is requested to perform.

(10) For Imagery captured on film, provide scanning pixel size value in dots per inch (DPI) or microns (µm). Include a summary of quality assurance test results.

(11) Stereo Imagery Deliverable, All Stereo Imagery must be free of abrasions, blemishes, scratches, tears, and irregularities and conform to the following requirements:

(a) Delivery medium— USB compatible external medium, such as an external hard drive. DVD may be used for data sets 40GB or less

(b) Stereo Image File Format—(uncompressed) TIFF (Tagged Image File Format) or VITec Scanner Raster Format. Naming and numbering of images must match the listings supplied in the aerial triangulation report

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# CHAPTER 4. DIGITAL ORTHOIMAGERY STANDARDS AND RECOMMENDED PRACTICES

## 4.1 Data Content Standard.

Develop the orthoimagery using the specifications defined by the Federal Geographic Data Committee in FGDC-STD-008-1999, except do not resample the imagery. Provide FGDC standard FGDC-STD-008-1999 compliant metadata for the orthoimagery.

## 4.2 Coverage

Create digital orthoimagery as individual tiles comprising a mosaic covering the extent of the entire project area.

## 4.3 Ground Sample Distance

Develop orthoimagery at the resolution of the original imagery used for analysis with a pixel ground sampled distance (GSD) between 0.25 feet and 1.0 feet (10 and 30 cm.). Do not resample the data.

## 4.4 Horizontal Positional Accuracy Testing and Reporting

Horizontal accuracy of orthoimagery must not exceed RMSE as outlined in Table 3-1 Map Accuracies as a Function of Photo/Map Scale in this AC at the 95% confidence level. Positional accuracy shall be tested and reported following the guidance in the National Standard for Spatial Data Accuracy (FGDC-STD-007.3-1998).

## 4.5 Deliverable Requirements

The data provider must develop and provide digital orthophotos for all projects using aerial or Satellite imagery technologies. For projects using LIDAR technologies, the point cloud fulfills this requirement.

## 4.6 Orthoimagery Delivery

Provide digital orthoimagery conforming to the following requirements:

**a.** Delivery medium— USB compatible external medium, such as an external hard drive. DVD may be used for data sets 40GB or less

**b.** File Image Format—(uncompressed) TIFF (Tagged Image File Format)

**c.** Submit orthoimagery to the following address:

Federal Aviation Administration
Airport Safety and Standards Contract Support Team
Innovative Solutions International
1201 Maryland Avenue S.W., Suite 510
Washington, D.C. 20024

# CHAPTER 5. LIGHT IMAGING DETECTION AND RANGING (LIDAR) SPECIFIC STANDARDS AND RECOMMENDED PRACTICES

## 5.1 What are the differences in LIDAR technologies in the collection of airport data?

**a. Using ALTM technologies.** The selection of airborne LIDAR technology for the surveying of airports requires the consideration of a broad range of factors. Most types of airborne LIDAR instrumentation have limited ability to capture detail below the 20 centimeter scale, but the method is relatively fast. In this context, LIDAT airborne surveys are ideal for capturing large facilities and defining an accurate framework of airport related features. However, some features may be below the level of detection of this LIDAR platform. Airborne LIDAR is also limited by the look angle, which may be up to 20° from vertical, looking forward of the aircraft. Some instruments are limited to a strictly nadir view. In this context airborne surveys benefit from multiple survey passes with differing flightline trajectories and from the integration of ground-based, higher resolution equipment. Airborne LIDAR scanner systems are subject to errors in pointing, range, and elevation as other surveying technologies. Elevation precision for most systems is less than 4 to ~10 inches. Planimetric precision is similar for most systems. However, the technology is limited in terms of the maximum number of points that can be collected along and across the flight track. Typical values for along track point spacing are ~12 to 16 inches with the across track point spacing being ~12 to 20 inches. Given these values, expected accuracy is clearly in the decimeter range for airborne survey point clouds. Moreover, given the minimum spacing of points, a single pass can capture features on the ground where the largest dimension of the object is greater than 28 to 36 inches in size. Flying repeat surveys with multiple look angles can improve capture resolution, but it is difficult to predict the complete representation of features in the final point cloud data set. Collection and processing times are highly dependent on the size of the survey area and the distance necessary to mobilize the equipment to the scanning site. Any request to survey an airport should seek a local provider, minimizing the mobilization costs. Processing of the data also requires a precise GPS base station solution to reference the data. Such solutions are regionally available and when suitable, the mission plan should adopt solutions for nearby permanent GPS solutions when available.

**b. Using MCLM technologies.** The equipment data providers use to collect MCLM data, to control the data, and to collect the quality control validation points should be able to collect the data at the necessary accuracy standards. Most MCLM systems use a time-of-flight approach to making spatial measurements and are accurate to ~ 2 to 20 inches. These accuracies are sufficient for capturing most airport related features at resolutions of ~4 to 39 inches. Collection and processing times depend on survey design (resolution) and the size of the survey. Maximum resolution data can easily exceed the display and processing capacities of most standard desktop configurations. This may require generating a processed data product for feature documentation. With such large data sets, processing can take days to weeks to achieve a data product usable for feature class recognition. For example using MCLM acquired data, an eight-mile stretch of freeway can be expected to take approximately 1 week to process into a finished deliverable point cloud and associated CADD or mesh model representation. Many airports will have considerably more paved surface than this stretch of road. Feature classification and or recognition will require additional processing time. Airport proponents must ensure they include processing time into their schedule.

**c. Using TLM technologies.** Most TLM systems are highly programmable and operate between two end-member modes: single pulse, or multi-pulse averaging. Single pulse systems are faster but have a larger range error. Multi-pulse systems will make 3 or more measurements and report an average point value after rejecting any outlier values. Scanners can be tripod mounted or mounted on a truck or an elevated boom. However, it should be noted, the factory specified accuracies are valid when the equipment is tripod mounted. Vehicle mounted and boom-mounted systems are subject to sway or mid-scan movement related to wind, tire expansion, engine vibration. Most systems are battery or AC powered and are highly portable, although some systems (scanner, power supply, tripod, and accessories) may way over 100 1bs. Some systems come with internal GPS receivers with antennas of varying quality. It is important to note about systems with GPS are only accurate to the millimeter level when combined with a local base-station solution. All systems produce x,y,z point clouds. Some provide tools for mapping Red, Green, Blue (RGB) values, but these are never as accurate as the LIDAR data itself, meaning some points may not have the correct RGB value assigned. Depending on the design of the instrument, TLM systems have mm to cm scale precision and accuracy and are capable of generating point clouds with sub-millimeter point spacing. In general, more precise systems use a focused beam design, limiting their maximum range. Data providers can provide statements of certified accuracy and limiting environmental or setup conditions that may limit scanner accuracy (e.g., wood or aluminum tripods tend to expand in sunlight and can change the position of the scanner during scan acquisition). Collection and processing time depends on survey specifications and deliverables. To scan a flat, featureless 7-acre bare Earth site at a resolution of 3 inches typically requires 8 hours to acquire the data with 3000 points/sec acquisition rate. Processing this same data may require up to 12 additional hours to provide a 6 inch contour digital elevation model based on 25-30 million points.

## 5.2 What are the basic considerations in using LIDAR to collect airport data?

**a. Multiple Look Angles**. LIDAR scanning technologies, regardless of type, are line-of-sight instruments and are not able to detect what is not visible to the sensor. Some airborne systems can penetrate water up to depths of 50 meters or more. However, these instruments are not considered eye-safe and require special precautions during deployment to avoid injuring people or animals. To acquire any object with complex geometry requires the sensor to scan the object from multiple perspectives. For ATLM systems this could require multiple flight line orientations to form a grid survey. For MCLM and TLM the user must reposition the sensor around the object to acquire data from multiple orientations. Combining the data into a single reference frame provides for the development of a full three dimensional representative point cloud. Shadows, or gaps in the data are either accepted by the user or the scanner is redeployed to a new location to fill in areas missed by the initial survey attempt.

**b. Multiple Resolutions and Managing Multiple Data Sources.** ATLM systems are capable of scanning geometries at the decimeter scale with centimeter scale precision. MCLM and TLM systems can typically capture data at centimeter scale resolution and in some cases millimeter scale precision. Data from different sources produces a point cloud where resolution can be tailored based on the desired capture resolutions of individual features within a survey area. Therefore, any survey planning to combine the different data acquisition techniques must have common georeferenced control points to ensure alignment in the final data set.

**c. Mission Planning.** Mission planning effects all aspects of the data collection process and can have a profound impact on data quality and suitability for any given application. Therefore, the definition and articulation of clear project goals early in the planning process is necessary. Although in many cases it may be possible to plan missions to collect data suitable for multiple applications, some applications may require specific collection parameters making the data unsuitable or prohibitively expensive for other applications.

**d. GNSS Survey Planning.** Both ATLM and MCLM are critically dependent on continuous high-quality GNSS position solutions for georeferencing during collection. As a result, plan data acquisitions during periods of good satellite visibility and low solar and geophysical variability. TLM is more resilient to periods of poor GNSS availability. TLM systems are able to overcome this with the use of additional control surveys before or after LIDAR data acquisition.

**e. Point Cloud Processing.** There are a variety of commercial and in-house applications to perform the various common steps of registration, classification, feature extraction, and modeling. The details of the steps required are often application specific so this AC does not provide a generic overview of the process. All details of this process should, however, be recorded by the data provider and supplied as part of the final deliverable along with the other required data products. In some cases, it may necessary for data providers to develop new tools and processes to meet specific project goals. In these instances it is suggested data providers assure the performance and documentation of their testing and quality assurance processes to ensure data quality.

## 5.3 What are the authorized uses of LIDAR in collecting airport data?

See Appendix A for a list of airport features defined in AC 150/5300-18 appropriate for collection by LIDAR systems.

## 5.4 Why must I calibrate LIDAR systems?

Radiometric Performance/Certification is necessary for all LIDAR scanners. The system electronics process signals at the speed of light and are therefore very sensitive. The sensors commonly use mechanical systems to direct the laser light pulses and require stepper motors capable of changing mirror positions in microdegrees. Both systems can wear and require calibration or servicing on a regular basis. All surveys must require some degree of certification. Factory certification is ideal, but qualified data providers can also devise, test, and certify the performance of their LIDAR.

## 5.5 What are the system calibration requirements for using LIDAR to collect airport data?

**a. Using ALTM technologies.** Inadequate calibration or incomplete calibration reports are cause for rejection of the data. Provide calibration reports for all LIDAR systems used in the project at the beginning and end of the project. The calibration reports must address each of the following types of calibration:

- Factory Calibration

- Boresight Calibration

Factory calibration of the LIDAR system must address both radiometric and geometric performance and calibration. (Note: the factory radiometric calibration does not eliminate the need for the radiometric qualification test for obstruction surveying.) The following briefly describes the parameter testing according to the manufacturers test procedures. Some of these procedures and parameters may be unique to a manufacturer since hardware varies from manufacturer to manufacturer.

(1) Radiometric Calibration (sensor response):

(b) Ensure the output of the laser meets specifications for pulse energy, pulse width, rise time, frequency, and divergence for the model of LIDAR being tested against the manufacturer's published specifications.

(c) Measure the receiver response from a reference target to ensure the response level of the receiver is within specification for the model of LIDAR system being tested against the manufacturer's specifications.

(d) Check the alignment between transmitter and receiver and certify the alignment is optimized and within the manufacturer's published specifications.

(e) Measure *T0* response of receiver (i.e., the response at the time the laser is fired) to ensure the *T0* level is the manufacturer's published specifications.

**b. Geometric Calibration:** Range Calibration – Determine rangefinder calibrations including first/last range offsets, temperature dependence, and frequency offset of rangefinder electronics, range dependence on return signal strength. Provide updated calibration values.

(1) Scanner Calibration – Verify that scanner passes accuracy and repeatability criteria. Provide updated scanner calibration values for scanner offset and scale.

(2) Position Orientation System (POS)-Laser Alignment – Alignment check of output beam and POS. Also, provide updated POS misalignment angles.

Overall, tune the system to meet the performance specifications for the model being calibrated. The data provider must ensure for each LIDAR system used, they perform the factory calibration within the manufacturer's recommended interval or more frequently, if required to demonstrate a stable calibration.

Sensor calibration is necessary to reduce or eliminate systematic errors in the LIDAR data. Specifically, the calibration procedures involve solving for a set of calibration parameters to minimize the mean square error using ground control and data in overlapping swaths. The specific set of calibration parameters is a function of the optical sensor model for the specific system, but may include, for example: roll, pitch, and range offsets, scanner scale, offset, or higher order polynomial coefficients. If performed properly, this calibration will ensure the highest possible data accuracy, while also eliminating artifacts in the data, such as discontinuities (vertical jumps) in swath overlap areas near the edges of scan lines, horizontal offsets between peaked rooftop positions in data from opposing flightlines, et cetera. Perform and document the results of this calibration for each project, or every month, or as dictated by analysis of the data, whichever interval is shortest. Additionally, any calibration procedure employing software must be documented and the reports generated by the software supplied along with a basic description of the software.

**b. Using MCLM technologies.** Scanning equipment used for airport survey applications should have a current certificate of calibration provided from the scanner manufacturer or certified accuracy established by a locally licensed surveyor. Any certification documentation should not be dated older than 6 months prior to instrument deployment date. If a certificate of calibration is provided by a licensed surveyor, the certificate must be accompanied by a description of calibration method, scanner precision and accuracy capabilities, and a description of maximum usable range and related instrument error that is a function of range. Any scanner used for airport survey applications must have a maximum range error of 15mm at 100 meter range and a maximum positional error of 20 mm. Errors tend to increase as a function of range and the larger the beam divergence the shorter the effective range of the scanner instrument. Scanners used for mapping airports should have a maximum divergence of 0.001°.

## 5.6 What are the specific requirements for Airborne Terrestrial LIDAR Mapping (ALTM) sensors?

**a. Data Acquisition Standards**

(1) Position Dilution of Precision (PDOP) and Vertical Dilution of Precision (VDOP) must be less than 3.

(2) Horizontal along-track and across-track LIDAR point spacing must not exceed the limits specified in Table 5-1.

**Table 5-1 identifies the horizontal and vertical point spacing requirements for ALTM sensors**

| LIDAR Data Acquisition point spacing parameters when supplemented with photography | |
|---|---|
| Maximum Across-Track Horizontal Point Spacing | 0.18 m (~7 inches) |
| Maximum Along-Track Horizontal Point Spacing | 0.18 m (~7 inches) |
| Maximum vertical Point Spacing (Tilted Sensor only) | 0.50 m (~18 inches) |
| Corresponding point Density | 30 points/m2 |

(3) Vertical point spacing shall not exceed the limits specified in Table 5-1

(4) Aircraft bank angle must not exceed 20 degrees.

(5) Ensure the flying height provides a high-probability of object detection, it is typically desirable to fly as low as possible, within the applicable eye-safety limits. Depending on the airport and the minimum eye-safe altitude, this may necessitate airspace coordination.

(6) Adjacent swaths must have a minimum overlap of 50% of the mean swath width. Overlap should be sufficient to fully capture tall objects within the proposed survey (Figure 5-1)

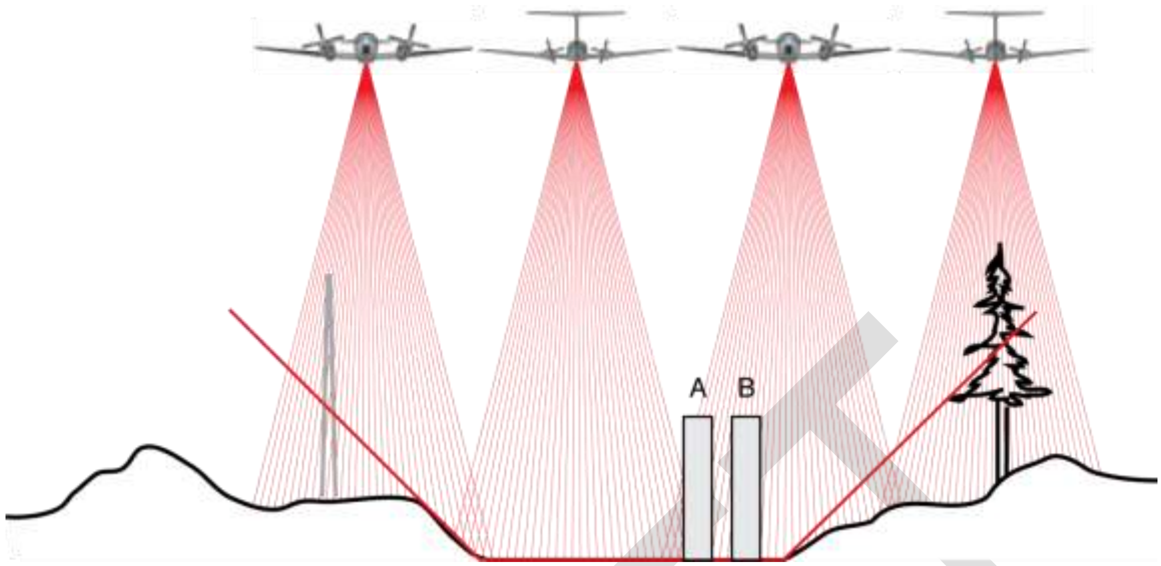


**Figure 5-1 illustrates a proposed flight plan failing to adequately capture tower A. A shift to the left of the flight line or increased overlap between flight lines can provide a predictable maximum height of data capture.**

(7) Fly flight lines in either direction; however, fly adjacent, parallel flight lines in opposite directions (reciprocal aircraft headings) to aid in eliminating systematic errors.

(8) When using LIDAR as a *supporting* tool in obstacle analysis, fly at least one cross-line (orthogonal to the "primary" flight lines) per runway approach (even if a tilted sensor is used) in order to assess internal consistency and calibration. If using a nadir-only sensor, the entire survey area must be covered with cross-lines. If only one cross-line is flown, it must be at the beginning of the approach surface (closet to the runway end), since this provides higher data density in the area where the greatest threat from obstacle intrusion may occur.

(9) The data provider must utilize a special test device within the survey area as a means of validating the system performance. The device will simulate real-world conditions of objects with the potential to intersect and protrude above the Obstacle Identification Surface and should be detectable by the LIDAR sensor. Point-cloud data of the object should appear in the complete data-set. See paragraph 2.1.i(11)(b) for construction and installation details.

**b. Waveform Digitization.** Full-waveform data is highly recommended. Research by the National Geodetic Survey (NGS) shows the use of full-waveform LIDAR data provides significantly more information about vertical structures. This assists in the detection and recognition of objects in the project area. If the data provider plans to acquire full-waveform data, they must submit a description of the waveform post-processing strategy to the government as part of the remote sensing plan.

## 5.7 What are the specific requirements for MCLM sensors?

**a. Redundancy.** Conduct the MCLM data capture to ensure redundancy of the data. Collect the data so there is an overlap of at least 20% between scans. The data provider must allow sufficient time to elapse between successive runs to ensure the satellite constellation has at least 3 different satellites between runs.

**b. Monitoring Acquisition.** Monitoring various component operations during the scan session is an important step in the QA/QC process. The system operator should be aware and note when the system encountered the most difficulty and be prepared to take appropriate action in adverse circumstances.

Monitor the MCLM equipment throughout the data collection to track the following as well as any other factors requiring monitoring:

- Loss of GNSS reception.
- Distance traveled with, or time duration of, uncorrected Inertial Measurement Unit (IMU) drift.
- Proper functioning of the laser scanner.
- Vehicle Speed.

**c. Local Transformation Points and Validation Points.** The data provider must perform a local transformation of the point clouds to increase the accuracy of the collected and adjusted geospatial data. There may be many different types of local transformations employed, however, the most common is a least squares adjustment of the horizontal and vertical residuals between established Local Transformation Points and the corresponding values from the point clouds to produce the transformation parameters of translation, rotation, and scale for the horizontal values and an inclined plane for the vertical values. These parameters are then applied to the point cloud to produce more accurate final geospatial data. Type A MCLM surveys require Local Transformation and Validation Points to have positional accuracies of ≤ 0.03feet horizontally and ≤ 0.02 feet vertically or better. Scan Type B MCLM surveys require Local Transformation and Validation Points to have horizontal and vertical positional accuracies of ≤ 0.10 feet or better.

**d. Data Processing.** Data processing for MCLM systems is similar to the processing of airborne LIDAR data. Clean and filter the data to remove errors. Georeference the data based on the Inertial Control Unit (ICU) and GPS data collected during acquisition and then classify the data into applicable classes. Accomplish (as practicable) auto classification for buildings, bare-earth, vegetation; however, because the look angle is horizontal through vegetative cover the signal may not successfully capture the bare Earth through a thick stand of vegetation.

**e. Data Filtering and Clean-up.** Objects passing through the survey generate isolated points requiring removal. Some errors are only detectable after multiple passes of data to insure reliability of error interpretation.

**f. Georeferenceing.** MCLM systems come with processing tools to resolve vehicle motion using ICU data collected during acquisition. Georeferencing is accomplished through recording GPS positional data referenced to resolved base station near the survey area. Processing should include reporting of relevant error sources related GPS performance.

**g. Data Integration.** A range of commercial products are available to combining LIDAR data from MCLM sources with LIDAR data from other sources. The time required depends on the size of surveys being merged. Report data errors associated with this type of processing as root mean squared fit errors and should be near the error ranges associated with the instrument with largest measurement errors (i.e., if TLM data has a range error of 2-3 cm, and MCLM data has an error range of 5-10 cm, then the error related to combining the two datasets should not exceed 5-10cm).

## 5.8 What are the specific requirements for MCLM sensors?

**a. Seasonal Considerations.** TLM signal quality is negatively impacted by vegetation, birds, insects, et cetera passing through or moving within the scan target area producing noise in the data that can be filtered. TLM is a line-of-sight instrument, and what is not visible to the eye is not visible to the scanner in most cases. The scanning of thick stands of vegetation is possible; however, the desired target may not be adequately captured for survey purposes. Removing vegetation or scanning during a seasonal "leaf-off" condition is preferred if targets are otherwise normally obscured by vegetation.

**b. Establishing Useful Scanner Range.** LIDAR scanners vary by design. Some have a laser source with focusing optics to improve the range finding precision but have limited usefulness beyond the designed focal point (~50 meters with one popular line of TLM scanner). Others have a cylindrical design to the laser beam, which imparts long-range capability but sacrifices precision. Both designs are subject to beam divergence, affecting the performance of cylindrical designed laser beam sources. Once the pulse leaves the unit, the beam becomes larger as a function of range. With increased laser spot size hitting the target, the noise within the return signal can increase, resulting in lower intensity of return and a reduction of precision. Most manufacturers will quote theoretical maximum ranges of 250-4000 meters, but in practice the maximum useful range in outdoor conditions can be 25-50% lower than the stated range specifications of some units.

**c. Scan Acquisition.** Data acquisition requires the placement of the scanner at the desired station, setting up the region of interest, executing the scan, and the recording of metadata. With mobile stop and go systems or tripod mounted systems, additional data collection can involve collection of backsite orientation information and or GPS coordinate position of the scanner itself. Additional metadata may include scanner orientation at instrument boot-up, and scan parameters used for programming the scan execution.

**d. Geo-reference Data Acquisition.** Most TLM systems are not equipped with backsite telescopes for measuring the orientation of a scanner at instrument start-up (the zero position for the scanner head at start-up has the instrument facing in the direction of the internal reference frame +y-axis).

**e. Data Processing.** Data processing generally begins by downloading data from the scanner and converting the data format into the preferred format for the processing software. Some TLM scanner systems come with their own processing tools and others rely on 3rd party software. Processing software of all types provide the tools to edit, clean, merge, and export data point clouds. Some vendors may have in-house software solutions. All processing software is proprietary. Available open source solutions even require a substantial annual fee to take advantage of well developed add-ons.

**f. Data Filtering and Clean-up.** Post acquisition processing of TLM data requires or at least benefits from clean-up and removal of errors related to objects passing through the scan area during acquisition.

**g. Scan Merging and acceptable error standards.** TLM data collected from multiple stations can be merged into a common reference frame if they include overlapping scan regions. Selection of scanning stations should account for adequate overlap; generally 20% overlap is sufficient to ensure appropriate coverage.

**h. Data Integration.** As with MCLM systems, it is possible to merge TLM scanner data with other types of data sets. The precision of the fit of datasets of differing resolutions is limited by the lowest precision and accuracy scan used in a merged dataset. Although the higher resolution scan will provide a more precise image of the scan area, its placement within a more course dataset (e.g., ATLM survey) is limited to the precision of the course survey unless referenced target(s) are captured in both low and high-resolution point clouds. When planning to combine TLM data with other data types, it is recommended targets be included in TLM scan area are also visible by other survey methods (e.g., laser theodolite, ATLM, MCLM, etc.).

**i. Applicability of RGB Point Clouds.** Most TLM scanner systems provide a solution to combine photographic color collected using an on-board camera with LIDAR point data. The resulting output is an XYZ-RGB data file useful for feature recognition. The procedure for assigning RGB values to the point cloud varies from vendor to vendor and none report any error analysis associated with these model solutions. At decimeter to meter scale resolutions the errors tend to be negligible but at the resolution of TLM systems many points can be assigned to a single pixel RGB value which may or may not represent reality. IT is not uncommon for TLM system to have errors along the edges of objects.

## 5.9 What are the data processing standards and recommended practices for using LIDAR in airport obstruction data collection projects?

Because small whippy thin objects are difficult for the LIDAR technologies to appropriately capture, certain rules apply to using LIDAR data in analyzing airport objects as potential obstructions.

**a. Data Cleaning and Filtering.** The data provider must avoid pre-filtering of the data. One aspect of LIDAR collection and post-processing for airport projects involving the analysis of objects as potential obstructions that is very different than for other end-user application (e.g., floodplain mapping) pertains to cleaning/filtering of the data. Many production workflows geared towards bare-earth terrain modeling involve a great deal of filtering/cleaning of LIDAR points very far up the processing chain, or even during data acquisition. For airport projects involving the analysis of objects as potential obstruction data clearing and filtering is not appropriate, as it can easily lead to removing points corresponding to reflections from obstructions, in some cases causing these obstructions to be missed. This is why we require the collection and submission of complimentary imagery supporting the LIDAR. The data provider must deliver the raw LIDAR point cloud (with absolutely no points removed either in the air or in post-processing) as one of the project deliverables. Additionally, the data provider must be extremely careful about any cleaning or filtering done during data analysis. In general, it is best to leave all points from the LAS file and allow the Object Detection step to handle filtering. Any pre-cleaning/filtering performed should be explicitly described in the report. Additionally, these filtered points must not be removed from the LAS file; instead they should be kept and attributed as "withheld" in the LAS file (classification bit encoding).

**b. Data Analysis Workflow.** Generating final obstruction data from the LIDAR point cloud is not a trivial task. It requires a tremendous amount of effort and planning. The data provider must not use the raw point cloud as the only source of data for object analysis against an obstruction identification surface but as a supplementary means associated with aerial imagery. Completing an obstruction analysis in this manner complicates the following tasks:

(1) distinguishing between returns from real objects and those due to noise or clutter,

(2) determining which points correspond to laser reflections from the same object, and

(3) attributing detected obstructions.

Data providers will use or integrate the steps in Figure 5-2 into their process to reduce or eliminate the possibility of missed objects and increase the probability of object detection. One critical aspect of this workflow is the placement of the object detection step before the OIS analysis step, so the OIS analysis is performed on extracted objects (e.g., trees, buildings, antennas, poles, towers, etc.), rather than on the raw LIDAR points.

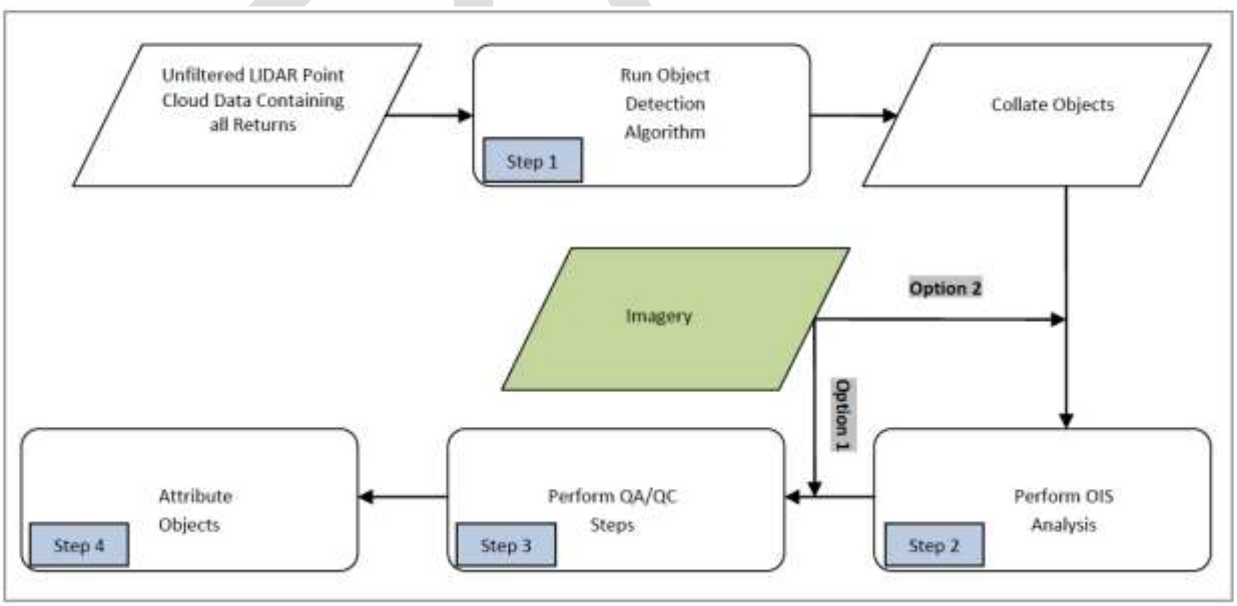


**Figure 5-2 illustrates the recommended steps for airport object analysis as obstructions (Source NOAA 2009.pdf)**

The data provider will identify their specific detection algorithms and processes in a step-by-step approach in the appropriate sections of the final report. The workflow in Figure 5-2 is generalized to accommodate the use of different algorithms and allows setting the detection threshold very low to minimize the probability of a miss (or equivalently, maximizes probability of detection). Using this process requires performing object detection and collation first and then performing the OIS analysis, then object-type attribution and validation using the aerial imagery. False alarms (or "false objects") due to ground clutter or noise are randomly distributed throughout the project area are typically automatically eliminated in the OIS analysis step, due to not penetrating or falling outside the OIS, and the remainder are easily removed during the image analysis steps. This inherent tolerance of conservative detection thresholds in the object extraction process is an important aspect of the process, since the key consideration in analyzing objects on and surrounding an airport for their obstruction potential is to avoid missing objects with the potential to jeopardize flight safety. The use of aerial imagery in using LIDAR as a supplementary source for object analysis is mandatory providing a complementary and independent data source. Data providers can introduce a slight variation on the workflow by introducing the aerial imagery at an earlier step to facilitate a primarily photogrammetric approach to obstruction detection, assisted by LIDAR.

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# CHAPTER 6. SATELLITE IMAGERY STANDARDS AND RECOMMENDED PRACTICES

## 6.1 RESERVED

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# CHAPTER 7. REQUIRED PROJECT DELIVERABLES

This advisory circular requires the airport proponent or authorized data provider submit information supporting the data acquisition project. In general submit all data captured in its original unedited format. Submit all supporting forms or documents in a non-editable format such as the Adobe PDF ™ format.

## 7.1 What are the deliverables for all remote sensing projects?

**a.** Remote Sensing Survey and Quality Control Plan

**b.** Control point information

**c.** The contractor shall also notify the government of any unusual circumstances occurring during the performance of this project with the potential to affect the deliverables or their quality and particularly of any deviation from the project specifications or Statement of Work.

**d.** Remote Sensing Final Project Report

## 7.2 What are the deliverables for projects incorporating aerial imagery technologies?

Aerial imagery projects require the submission of the following items,

**a.** Control points and associated documentation

**b.** Camera calibration certificate or certificate of compliance with manufacturers procedures

**c.** Photographic Flight Report

**d.** Stereoscopic imagery for used in analysis

**e.** Digital orthoimagery.

## 7.3 What are deliverables for projects incorporating LIDAR ALTM technologies?

**a. Control Point information.** If using the test apparatus described earlier report the proposed location of this target as well as ground control and validation points.

**b. LIDAR Raw Data.** Submit the completed data collection raw output. Formats should include proprietary raw data formats for archival purposes and standard formats that include both unfiltered and filtered and classified point clouds.

**c. LIDAR Products.** Required products include: LIDAR point cloud files, intensity images, attributed objects/obstructions and other products described in the appropriate advisory circulars.

**d. Imagery.** Deliver imagery according to the standards outlined in the AC.

**e. Flight Reports.** Submit the completed, original LIDAR Flight Logs with the data for government review.

**f. GPS Files.** GLOBAL POSITIONING SYSTEM (GPS)/INERTIAL MEASUREMENT UNIT (IMU) FILES – The data provider must submit the original, raw data files and processed trajectory files for government review.

**g. Airborne Positioning and Orientation Report.** Submit raw GPS and IMU data (in the manufacturer's format) with the final processed GPS trajectory and post-processed IMU data. Also submit a report covering the positioning and orientation of the LIDAR.

**h. Range and Scanner Angle Files.** The contractor shall submit the original, raw data files for government review.

**i. GPS Check Points.** Submit an organized list of all GPS points used for the project as base stations and check points. Indicate which GPS points are pre-existing ground control and which stations are new and positioned relative to the NSRS.

**j. Calibration Reports.** There is no standard format for the calibration reports. However, the calibration reports shall contain, at a minimum, the following information:

- The date the calibration was performed.
- The name of the person, company, or organization responsible for performing the calibration.
- The methods used to perform the calibration.
- The final calibration parameters or corrections determined through the calibration procedures.
- A discussion of the results

Sensor Maintenance Reports - submit maintenance history of the sensor(s) used in data collection.

## 7.4 What are the deliverables for projects incorporating LIDAR MCLM technologies?

The deliverables from a mobile scanning project should be specified in the contract with the provider. If a point cloud is the final deliverable, considerable office time will be required to extract data in a CADD/DTM usable format. The ratio of field time to office time will vary greatly with the complexity of the scanned roadway. Resources for data extraction (computers, programs, and trained personnel) must be available. If the mobile scan provider is delivering a finished CADD/DTM file, client office time will be reduced to QA of the final product. The simplest form of the processed LIDAR data is a "point cloud", which can be saved in a scanner specific format or an ASCII file format containing XYZI (X, Y, Z coordinates and return intensity values) geo-referenced data. If image overlay data is available, the post-processed point cloud may be delivered in an ASCII file containing XYZIRGB (X, Y, Z coordinates, return intensity, red, green, and blue color values).

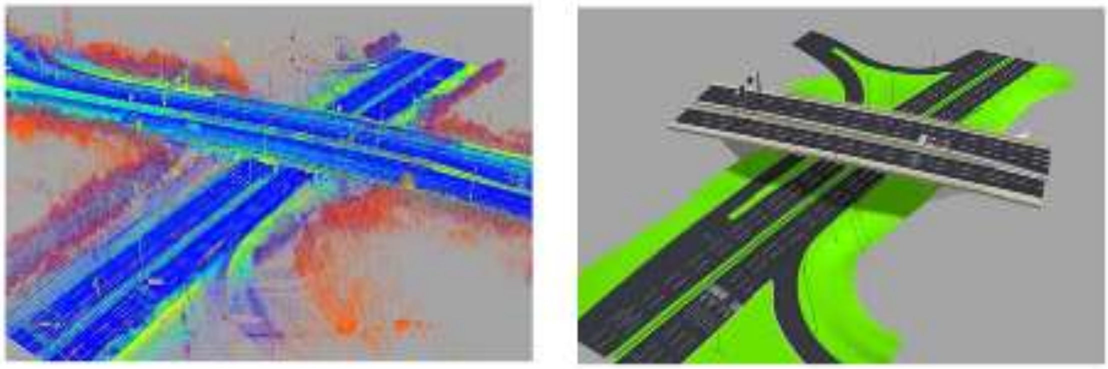

**Figure 7-1 shows an example of a point cloud dataset and the same data converted into a CADD model.**

Point cloud data can be imported into various software packages. Further data manipulation and/or fusing other types of data and analytical tools with the imported point cloud create a variety of value-added products.

In addition, a readme file specifying the units and datum of the XYZ coordinates in ASCII point cloud files should be provided. The geo-referenced image files (in common image format such as jpg, tiff, png, etc) should also be deliverable if they are available. Figure 7-1 shows an example of a point cloud dataset and the same data converted into a CADD model.

Deliverables specific to MCLM surveys may include, but are not limited to:

- XYZI files in ASCII, CSV, or other specified format
- Registered point clouds
- Digital video or photo mosaic files
- Survey narrative report and QA/QC files

**k. Raw data formats.** Raw data formats from mobile systems are generally kept within a proprietary format that can be exported into any portable format that is desired. Points can be processed into a classified point cloud stored in a LAS format (Log ASCII Standard, a commonly accepted public file format for storing and exchanging LIDAR point data)

**l. Modeled data.** Raw data from MCLM surveys are generally too cumbersome for client processing. Therefore, most vendors are prepared to provide CADD or mesh model representations based on the raw data that are suitable for survey grade analysis and use. The maximum resolution of such models is around 200% of the survey resolution; however, accuracy may exceed or at least approach the measurement accuracy of the MCLM instrumentation. The latter requires sufficient laser spot overlap to generate models with minimum error.

**m. Survey Properties.** The documentation of a mobile scanning project must show a clear data lineage from the published primary control to the final deliverables. The data path of the entire process must be defined, documented, assessable, and allow for identifying adjustment or modification. 3D data without a documented lineage is susceptible to imbedded mistakes, and difficult to adjust or modify to reflect changes in control. An additional concern is that a poorly documented data lineage would not be legally supportable. The survey narrative report, completed by the Party Chief, shall contain the following general information, the specific information required by each survey method, and any appropriate supplemental information.

- Project name & identification
- Survey date, limits, and purpose
- Datum, epoch, and units
- Control found, held, and set for the survey
- Personnel, equipment, and surveying methods used
- Problems encountered
- Any other pertinent information such as GNSS observation logs
- Dated signature and seal of the Party Chief

**n.** Documentation specific to mobile terrestrial laser scanning surveys includes, but is not limited to:

(1) Control Lineage or Pedigree

- Primary control held or established
- Project control held or established
- Control target points
- Validation points
- Adjustment report for control and validation points

(2) Control for Scanner Registration

- Control target points
- Local transformation points
- Validation points
- GNSS Accuracy Report
- IMU Accuracy Report
- Adjustment report for control

(3) Registration Reports

- Results of target and cloud to cloud registration

- QA/QC reports as described in Section 15-11.7
- Results of finished products to validation points
- MCLM survey narrative report

### 7.5 What are the deliverables for projects incorporating LIDAR TLM technologies?

Identify deliverables for scanning projects in the planning stage. However, TLM systems produce a great deal of data that may prove useful beyond the expected outcomes. In this context, the client should seek to receive the raw data, the registered data, the filtered and processed data, and all related acquisition data including field notes and digital photographs. Additional deliverables should include QA/QC analysis, metadata, and useful definitions of procedures.

**a.** Deliverables specific to TLM surveys may include, but are not limited to:

(1) XYZI or XYZ RGB files in ASCII, CSV, XML, or other specified format

(2) Registered point clouds

(3) Current Caltrans Roadway Design Software files

(4) Current Caltrans Drafting Software files

(5) Digital photo mosaic files

(6) 3D printing technology physical scale models of the subject

(7) Survey narrative report and QA/QC files

(8) FGDC compliant metadata files conforming to the current FAA standard

**b. Raw data formats.** Most scanners export data in proprietary, compressed data formats and are only useful to the client if there is a means to access these files. Because they are small these raw data files are useful for archiving the data from any TLM survey. The most portable format, but unfortunately the least efficient for storage is ASCII formatted files. These files will generally contain 3 to 7 columns of data and include XYZ point position data, intensity (I), and red/green/blue (RGB) color assignments. Unlike airborne terrestrial LIDAR mapping, TLM data does not usually collect full waveform data collection. In those projects where TLM, full wave form technology is used the raw point cloud should include:

(1) All returns, all collected points, fully calibrated and adjusted to ground, by swath.

(2) Fully compliant LAS v1.2 or v1.3, Point Record Format 1, 3, 4, or 5

(3) LAS v1.3 deliverables with waveform data are to use external “auxiliary” files with the extension “.wdp” for the storage of waveform packet data. See the LAS v1.3 Specification for additional information.

(4) Georeference information included in all LAS file headers

(5) GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse.

(6) Intensity values (native radiometric resolution)

(7) 1 file per swath, 1 swath per file, file size not to exceed 2GB.

Newer systems do provide the option to collect the full waveform, which results in raw data formats similar to that of ATLM or MCLM systems.

**c. Modeled data.** Similar to MCLM systems, TLM produces more data than most clients are prepared to computationally handle. Therefore, the generation of modeled meshes suitable for display in CADD systems or geographic information systems is a common modeled data deliverable. In most cases, with sufficient sampling density and spot overlap, the modeled surface data can be more accurate than the original LIDAR data.

# CHAPTER 8. DATA REVIEW AND ACCEPTANCE

## 8.1 Data review and acceptance requirement

The FAA is responsible for conducting the data validation and verification of work products performed in accordance with this advisory circular.

**a. Review Process.**

(1) Receipt Acknowledgment. The FAA will acknowledge the date the imagery and associated deliverables were received in the Airports GIS project file within 2 working days of receipt. They will include a note in the comments section of the project when they expect to start and finish the review for the information of the FAA, contractor and airport sponsor.

(2) Imagery Acceptance Criteria. The imagery will be evaluated by the criteria listed below:

- Ground Sample Distance (GSD)—GSD is between 10 and 30 cm.
- Stereo Coverage—Imagery must have sufficient overlap to permit stereo coverage of the entire area for analysis.
- Geometric Fidelity—Collection and processing of the image data will maintain, within accuracy requirements, the relationship between measurements made in the image model and real world coordinates.
- Geo-Referencing—The imagery is geo-referenced and the source data used for completing the geo-referencing is provided.
- Positional Accuracy—Positions of well-defined points determined from the stereo imagery must be within 1 meter relative to the National Spatial Reference System (NSRS) referenced to North American Datum of 1983 (NAD83) and the North American Vertical Datum of 1988 (NAVD88) at the 95 percent confidence level for Easting, Northing and Orthometric Height.
- Resolution—Imagery must be sufficiently sharp to allow identification, analysis, and measurement of airport features and obstructions.
- Image Quality—the imagery must be clear, sharp, and evenly exposed across the format. The imagery must be free from clouds, cloud shadows, smoke, haze, scratches, and other blemishes interfering with the intended use of the imagery.
- Acquisition Date—the imagery should be acquired within the 18 month period prior to the airport ground survey.

- Foliage – Imagery collected at time of full leaf foliage if appropriate.

(3) Imagery Acceptance Review. The FAA will formally accept the imagery by providing an imagery usability report in the project file of Airport GIS. This review typically is completed within five days of the start date but could take longer depending on workload. Once a favorable usability determination is made by FAA the contractor may then submit the airport ground survey data. If FAA determines the imagery is unacceptable, the contractor must re-submit new imagery as soon as possible for review. This is the primary reason for submitting the imagery well in advance of the airport ground survey portion.

# CHAPTER 9. POINTS OF CONTACT

## 9.1 Advisory Circular Questions/Comments

Contact the following offices for additional information or clarification regarding their respective areas.

- For questions regarding these specifications, the Airport Surveying/GIS Program or Airports GIS, contact:

  FAA Airport Surveying-GIS Program Manager

  Email: 9-AWA-ARP-AirportSurveyingGIS@faa.gov

- For questions regarding imagery review, usability, or review times contact the following FAA personnel.

  FAA Airport Safety and Standards Contract Support Team
  Innovative Solutions International
  1201 Maryland Avenue S.W.
  Suite 510
  Washington, D.C. 20024
  PHONE

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# APPENDIX A – LIDAR USABILITY TABLE

The following table presents each of the features within AC 150/5300-18 and defines the usability of the different LIDAR sensors to capture the information. The table also provides any special capture requirements for the collection of each feature by sensor. For example, the first entry in the table, ALTM is not acceptable to define this feature; however, using Reference Targets, the use of MCLM and TLM sensors is an acceptable capture method. In this table, the abbreviation "NA" indicates the use of LIDAR to capture the feature using the sensor is not acceptable.

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | ATLM | MCLM | TLM |
| Airfield | Aircraft Gate Stand | NA | Requires a LIDAR Reference target | Requires a LIDAR Reference target |
| Airfield | AircraftNonMovementArea | NA | Requires a LIDAR Reference target at line endpoints | Requires a LIDAR Reference target at line endpoints |
| Airfield | AirOperationsArea | Requires a LIDAR Reference target on vertices | Requires a LIDAR Reference target on vertices | Requires a LIDAR Reference target on vertices |
| Airfield | AirfieldLight | Requires a LIDAR Reference target | Acceptable | Acceptable |
| Airfield | ArrestingGear | NA | NA | NA |
| Airfield | FrequencyArea | Requires a LIDAR Reference target on vertices | Requires a LIDAR Reference target on vertices | Requires a LIDAR Reference target on vertices |
| Airfield | PassengerLoadingBridge | Requires Multiple Look Angles | Requires Multiple Look Angles | Requires Multiple Look Angles |
| Airfield | RunwayCenterline | NA | Requires a LIDAR Reference Target at line endpoints | Requires a LIDAR Reference Target at line endpoints |
| Airfield | RunwayHelipadDesignSurface | NA | NA | NA |

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | ATLM | MCLM | TLM |
| Airfield | RunwayIntersection | Acceptable | Requires a LIDAR Reference target at line endpoints | Requires a LIDAR Reference Target at line endpoints |
| Airfield | RunwayLAHSO | Acceptable | Acceptable | Acceptable |
| Airfield | RunwayElement | Acceptable | Acceptable | Acceptable |
| Airfield | Stopway | Acceptable | Acceptable | Acceptable |
| Airfield | TaxiwayHoldingPosition | Requires a LIDAR Reference target at line endpoints | Requires a LIDAR Reference Target at line endpoints | Requires a LIDAR Reference target at line endpoints |
| Airfield | AirportSign | Requires a LIDAR Reference target | Requires a LIDAR Reference target | Requires a LIDAR Reference target |
| Airfield | Apron | Requires interpretation from data | Requires interpretation form data | Requires interpretation from data |
| Airfield | Deicing Area | Requires LIDAR Reference target on vertices | Requires LIDAR Reference target on vertices | Requires LIADR Reference target on vertices and sufficient view angle |
| Airfield | TouchDownLiftOff | NA | Requires interpretation from data | Requires interpretation from data |
| Airfield | MarkingArea | Requires interpretation from data | Requires interpretation from data | Require interpretation from data |
| Airfield | MarkingLine | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |
| Airfield | MovementArea | Requires LIDAR Reference target on vertices | Requires LIDAR Reference target on vertices | Requires LIDAR reference target on vertices |
| Airfield | Runway | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | ATLM | MCLM | TLM |
| Airfield | RestrictedAccessBoundary | Requires LIDAR reference targets on line endpoints and interpretation from data | Requires LIDAR reference targets on line endpoints and interpretation from data | Requires LIDAR reference targets on endpoints and interpretation from data |
| Airfield | RunwayArrestingArea | Interpreted from data | Requires multiple look angles and interpretation from data | Requires multiple look angles and interpretation from data |
| Airfield | RunwayBlastPad | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |
| Airfield | RunwayEnd | Not acceptable | Requires LIDAR reference target | Requires LIDAR reference target |
| Airfield | RunwayLabel | Requires LIDAR reference target at location | Requires LIDAR Reference target at location | Requires LIDAR Reference Target at location |
| Airfield | RunwaySafetyAreaBoundary | Requires LIDAR Reference targets on vertices | Requires LIDAR Reference Target on vertices | Requires LIDAR Reference target on vertices |
| Airfield | Shoulder | Requires interpretation from data | Requires Interpretation from data | Requires interpretation from data |
| Airfield | TaxiwayIntersection | Requires interpretation from data | Requires interpretation from data | Requires sufficient look angle and interpretation from data |
| Airfield | TaxiwayElement | Requires interpretation from data | Requires interpretation from data | Requires sufficient look angle and interpretation from data |
| Airspace | LandmarkSegment | Requires interpretation from data | Requires interpretation from data | Requires multiple look angles |

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | ATLM | MCLM | TLM |
| Airspace | Obstacle | Requires complimentary imagery, sufficient look angle and interpretation from data | Requires complimentary imagery and interpretation from data | Requires complimentary imagery and interpretation from data |
| Airspace | ObstructionArea | Requires complimentary imagery, sufficient look angle and interpretation from data | Requires complimentary imagery, sufficient look angle and interpretation from data | Requires complimentary imagery, sufficient look angle and interpretation from data |
| Airspace | ObstructionIdSurface | NA | NA | NA |
| Airspace | RunwayProtectArea | NA | NA | NA |
| Cadastral | AirportBoundary | NA | NA | NA |
| Cadastral | AirportParcel | NA | NA | NA |
| Cadastral | County | NA | NA | NA |
| Cadastral | EasementAndRightsofWay | NA | NA | NA |
| Cadastral | FAARegionArea | NA | NA | NA |
| Cadastral | LandUse | NA | NA | NA |
| Cadastral | LeaseZone | NA | NA | NA |
| Cadastral | Municipality | NA | NA | NA |
| Cadastral | Parcel | NA | NA | NA |
| Cadastral | State | NA | NA | NA |
| Cadastral | Zoning | NA | NA | NA |
| Environmental | EnvironmentalContaminationArea | NA | NA | NA |
| Environmental | FaunaHazardArea | NA | NA | NA |
| Environmental | Floodzone | NA | NA | NA |

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | ATLM | MCLM | TLM |
| Environmental | FloraSpeciesSite | Requires LIDAR reference targets on vertices | Requires LIDAR reference targets on vertices | Requires LIDAR reference targets on vertices |
| Environmental | ForestStandArea | Requires LIDAR reference targets on vertices | Requires LIDAR reference targets on vertices | Requires LIDAR reference targets on vertices |
| Environmental | HazardousMaterialStorageSite | NA | NA | NA |
| Environmental | NoiseContour | NA | NA | NA |
| Environmental | NoiseIncident | NA | NA | NA |
| Environmental | NoiseMonitoringPoint | NA | NA | NA |
| Environmental | SampleCollectionPoint | NA | NA | NA |
| Environmental | Shoreline | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |
| Environmental | Wetland | NA | NA | NA |
| Geospatial | AirportControlPoint[1] | Requires LIDAR reference target on point and interpretation from data | Requires LIDAR reference target on point and interpretation from data | Requires LIDAR reference target on point and interpretation from data |
| Geospatial | CoordinateGridArea | NA | NA | NA |
| Geospatial | ElevationContour | LIDAR not possible | LIDAR not possible | LIDAR not possible |
| Geospatial | ImageArea | NA | NA | NA |

[1] Exception: Data providers may use any LIDAR sensor without targets in modeling the runway profile points, however, it does requires data interpretation.

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | ATLM | MCLM | TLM |
| Manmade Structures | Building | Requires interpretation from data | Requires multiple look angles and interpretation from data | Requires multiple look angles and interpretation from data |
| Manmade Structures | ConstructionArea | NA | NA | NA |
| Manmade Structures | Roof | Requires interpretation from data | Requires multiple look angles and interpretation from data | Requires multiple look angles and interpretation from data |
| Manmade Structures | Fence | NA | Requires multiple look angles | Requires multiple look angles |
| Manmade Structures | Gate | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |
| Manmade Structures | Tower[2] | Interpreted from data | Interpreted from data | Interpreted from data |
| NavigationalAids | NavaidCriticalArea | NA | NA | NA |
| NavigationalAids | NavaidEquipment - Airport Beacon | Requires interpretation from data | Requires interpretation from data | Requires interpretation ffrom data |
| NavigationalAids | NavaidEquipment - Air Route Surveillance Radar (ARSR) or Airport Surveillance Radar (ASR) | Requires interpretation from data | Requires interpretation from data | Requires interpretation form data |
| NavigationalAids | | | | |
| NavigationalAids | NavaidEquipment - Approach Light System[3] | NA | Requires LIDAR reference targets at line endpoints | Requires LIDAR reference targets at line endpoints |
| NavigationalAids | NavaidEquipment - Back Course Marker (BCM) | NA | Requires interpretation from data | Requires interpretation from data |

[2] Data providers should use caution in collecting Towers using LIDAR. Very tall and slender towers are difficult to capture using LIDAR. If used to support obstacle analysis, the data provider must use complimentary imagery to support the analysis.
[3] A reference target is required on each end of each light bar or individual fixture to adequately capture this feature

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | **ATLM** | **MCLM** | **TLM** |
| NavigationalAids | NavaidEquipment - Distance Measuring Equipment (DME) | NA | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Glide Slope - End Fire (GS) | Requires a LIDAR reference target on each end of each antenna array and interpretation from data | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Fan Marker (FM) | NA | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Glideslope (GS) | NA | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - ground controlled approach touchdown reflectors | NA | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Inner Marker | NA | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Localizer (LOC) | Requires a LIDAR reference target on each end of the antenna array, horizontal survey point and interpretation from data | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Localizer Type Aid (LDA) | NA, insufficient resolution capabilities | sufficient resolution, interpreted from data | sufficient resolution, interpreted from data |
| NavigationalAids | NavaidEquipment - Middle Marker | NA | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment -MLS Azimuth Antenna (MLSAZ) | NA | Requires interpretation from data | Requires interpretation from data |

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | ATLM | MCLM | TLM |
| NavigationalAids | NavaidEquipment - MLS Elevation Antenna (MLSEZ) | NA | Requires interpretation form data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Non-Directional Beacon (NDB) | NA | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Outer Marker (OM) | NA | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Precision Approach Path Indicator (PAPI) System | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Precision Approach Radar (PAR) Touchdown Reflectors | NA | Requires interpretation from data | Requires interpretation form data |
| NavigationalAids | NavaidEquipment - Pulse Light Indicator (PLASI) | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Pulsating Visual Approach Slope Indicator (PVASI) | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidEquipment - Runway End Identifier Lights (REIL) | NA | Requires interpretation of data | Requires interpretation of data |
| NavigationalAids | NavaidEquipment - Simplified Directional Facility (SDF) | NA | Requires interpretation of data | Requires interpretation of data |
| NavigationalAids | NavaidEquipment - Tactical Air Navigation (TACAN) | Requires interpretation from data | Requires interpretation of data | Requires interpretation of data |
| NavigationalAids | NavaidEquipment - Tricolor Visual Approach Slope Indicator System (TRCV) | NA | Requires interpretation of data | Requires interpretation of data |
| NavigationalAids | NavaidEquipment - "T" Visual Approach Slope Indicator System (T-VASI) | Requires interpretation of data | Requires interpretation of data | Requires interpretation of data |
| NavigationalAids | NavaidEquipment - VHF Omni Directional Range (VOR) | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | ATLM | MCLM | TLM |
| NavigationalAids | NavaidEquipment - Visual Approach Slope Indicator System (VASI) | Requires LIDAR reference target at horizontal reference point and interpretation from data | Requires LIDAR reference target at horizontal reference point and interpretation from data | Requires LIDAR reference target at horizontal reference point and interpretation from data |
| NavigationalAids | NavaidEquipment - VOR/TACAN (VORTAC) | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |
| NavigationalAids | NavaidSite | Requires LIDAR reference targets on vertices | Requires LIDAR reference targets on vertices | Requires LIDAR reference targets on vertices |
| SeaPlane | WaterOperatingArea | NA | NA | NA |
| SeaPlane | WaterLaneEnd | NA | NA | NA |
| SeaPlane | TaxiChannel | NA | NA | NA |
| SeaPlane | TurningBasin | NA | NA | NA |
| SeaPlane | NavigationBuoy | NA | NA | NA |
| SeaPlane | SeaplaneRampCenterline | Requires interpretation from data | Requires interpretation from data | Requires sufficient look angle and interpretation from data |
| SeaPlane | SeaplaneRampSite | Requires interpretation from data | Requires interpretation from data | Requires sufficient look angle and interpretation from data |
| SeaPlane | DockArea | Requires interpretation from data | Requires multiple look angles | Requires multiple look angles |
| SeaPlane | AnchorageArea | water/buoy | water/buoy | water/buoy |
| Security | SecurityArea | NA | NA | NA |
| Security | SecurityIdDisplayArea | NA | NA | NA |

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | ATLM | MCLM | TLM |
| Security | SecurityPerimeterLine | NA | NA | NA |
| Security | SterileArea | NA | NA | NA |
| Surface Transportation | Bridge | NA | Requires interpretation from data | Requires interpretation from data |
| Surface Transportation | DrivewayArea | Requires LIDAR reference targets on vvertices | Requires LIDAR reference targets on vertices or interpretation from data | Requires sufficient look angle, LIDAR reference targets on vertices, or interpreted from data |
| Surface Transportation | DrivewayCenterline | NA | NA | NA |
| Surface Transportation | ParkingLot | Requires LIDAR reference targets on vertices | Requires LIDAR reference targets on vertices or interpretation from data | Requires sufficient look angle, LIDAR reference targets on vertices, or interpreted from data |
| Surface Transportation | RailroadCenterline | Requires interpretation from data | Requires interpretation from data | Requires sufficient look angle and interpretation from data |
| Surface Transportation | RailroadYard | Requires interpretation from data | Requires multiple look angles | Requires multiple look angles |
| Surface Transportation | RoadCenterline | Requires interpretation form data | Requires interpretation from data | Requires interpretation from data |
| Surface Transportation | RoadPoint | Requires LIDAR reference target on point | Requires LIDAR reference target on point | Requires LIDAR reference target on point |
| Surface Transportation | RoadSegment | Requires interpretation from data | Requires interpretation from data | Requires sufficient look angle and interpretation from data |

| Feature Group | Feature Name | Sensor Specific Capture Requirements | | |
|---|---|---|---|---|
| | | ATLM | MCLM | TLM |
| Surface Transportation | Sidewalk | Requires interpretation from data | Requires interpretation from data | Requires sufficient look angle and interpretation from data |
| Surface Transportation | Tunnel | NA | NA | NA |
| Utilities | TankSite | Requires interpretation from data | Requires interpretation from data | Requires interpretation from data |
| Utilities | UtilityLineA | NA | NA | NA |
| | UtilityLineB | NA | NA | NA |
| | UtilityLineC | NA | NA | NA |
| | UtilityLineD | NA | NA | NA |
| Utilities | UtilityPointA | NA | NA | NA |
| | UtilityPointB | NA | NA | NA |
| | UtilityPointC | NA | NA | NA |
| | UtilityPointD | NA | NA | NA |
| Utilities | UtilityPolygonA | NA | NA | NA |
| | UtilityPolygonB | NA | NA | NA |
| | UtilityPolygonC | NA | NA | NA |
| | UtilityPolygonD | NA | NA | NA |

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# APPENDIX B – GLOSSARY

Many of these definitions are from other FAA ACs. Other definitions are from National Digital Elevation Program (NDEP), 2004 and ASTM E 2544-09b. When adequate definitions were not available from an official source, they were carefully developed as needed for this document.

**3D Imaging System** – A non-contact measurement instrument used to produce a 3D representation (for example, a point cloud) of an object or site. (ASTM E 2544-09b)

**Accuracy** – The degree of conformity with a standard, or a value accepted as correct. Precision is the degree of uniformity of repeated measurements or events. For example, repeat measurements of the distance between two points may exhibit a high degree of precision by virtue of the relative uniformity of the measurements. However, if a "short" tape were used in the measurements, accuracy would be poor in that the measured distance would not conform to the true distance between the points. Surveying and mapping accuracy standards should include three elements: (1) a stated variation from a true value or a value accepted as correct, (2) the point to which the new value is relative, and (3) the probability that the new value will be within the stated variation. For example, "Horizontal accuracy will be 10 cm relative to the nearest Continuously Operating Reference Station (CORS) at the 95 percent confidence level." (AC 150/5300-18B)

**Beam Diameter, ($d\sigma$)** – For a laser beam with a circular irradiance pattern, the beam diameter is the extent of the irradiance distribution in a cross-section of the laser beam (in a plane orthogonal to its propagation path) at a distance *z* and is given by:

$$d_{\sigma}(z) = 4\sigma(z)$$

where:

$$\sigma(z) = \sigma_x(z) = \sigma_Y(z)$$

$\sigma_x(z)$, $\sigma_y(z)$ = the square roots of the second order moments

For a laser beam with a Gaussian distribution of irradiance, the beam diameter is often defined as the distance across the center of the beam for which the irradiance, *I* equals $1/e^2$ of the maximum irradiance (where *e* is the base of the natural logarithm. The area inside a circle with this diameter and centered at the beam center will contain 86.5 % of the total beam irradiance. (ASTM E 2544-09b)

**Beam Divergence Angles ($\theta_{\sigma x}$, $\theta_{\sigma y}$)** – Measure for the asymptotic increase of the beam widths, $d_{\sigma x}(z)$ and $d_{\sigma x}(z)$, with increasing distance, *z*, from the beam waist locations, $z_{0x}$ and $z_{0y}$, given by:

$$\theta_{\sigma x} = \lim_{(z - z_{0x}) \to \infty} \frac{d_{\sigma x}(z)}{z - z_{\sigma x}}$$

$$\theta_{\sigma y} = (z - z_{0y}^{lim}) \rightarrow \infty \frac{d_{\sigma y}(z)}{z - z_{\sigma y}}$$

(ASTM E 2544-09b)

**Bench Mark** – A relatively permanent natural or artificial material object bearing a marked point whose elevation above or below an adopted surface (datum) is known. (AC 150/5300-18B)

**Consolidated Vertical Accuracy** – The result of a test of the accuracy of 40 or more check points (z-values) consolidated for two or more of the major land cover categories, representing both the open terrain and other land cover categories. Computed using a nonparametric testing method (95th Percentile), a consolidated vertical accuracy is always accompanied by a fundamental vertical accuracy. (Refer to Fundamental and Supplemental Vertical Accuracies.) (NDEP, 2004)

**Control Station** – A point on the ground whose position and/or elevation is used as a basis for obtaining positions and/or elevations of other points. (AC 150/5300-18B)

**Datum** – In general, a point, line, surface, or set of values used as a reference. A "geodetic datum" is a set of constants specifying the coordinate system and reference used for geodetic control (refer to Control Station), i.e. for calculating coordinates of points on the earth. At least eight constants are needed to form a complete datum: three to specify the location of the origin of the coordinate system; three to specify the orientation of the coordinate system; and two to specify the dimensions of the reference ellipsoid. Any point has a unique X, Y, Z datum coordinate which can be transformed into latitude, longitude, and ellipsoid height (height relative to the ellipsoid). A "horizontal control datum" is a geodetic datum specified by two coordinates (latitude and longitude) on the ellipsoid surface, to which horizontal control points are referenced. A "vertical datum" is a theoretical equipotential surface with an assigned value of zero to which elevations are referenced. (Refer to GEOID.) (AC 150/5300-18B)

**Digital Elevation Model (DEM)** – The digital cartographic representation of the elevation of the land at regularly spaced intervals in x and y directions, using z-values referenced to a common vertical datum. (NDEP, 2004)

**Digital Surface Model (DSM)** – Similar to DEMs or DTMs, except that they depict the elevations of the top surfaces of buildings, trees, towers, and other features elevated above the bare earth. DSMs are especially relevant for telecommunications management, forest management, air safety, 3-D modeling and simulation. (NDEP, 2004)

**Digital Terrain Model (DTM)** – DTMs may be identical to DEMs, but they may also incorporate the elevation of significant topographic features on the land and change points and breaklines that are irregularly spaced so as to better characterize the true shape of the bare earth terrain. The net result of DTMs is that the distinctive terrain features are more clearly defined, and contours generated from DTMs more closely approximate the real shape of the terrain. Such DTMs are normally more expensive and time consuming to produce than uniformly spaced

DEMs because breaklines are ill suited for automation; but the DTM results are technically superior to standard DEMs for many applications. (NDEP, 2004)

**Ellipsoid Height** – The distance between a point and the reference ellipsoid taken along the perpendicular to the ellipsoid. Ellipsoid heights are the heights resulting from GPS observations. Ellipsoid heights are positive if the point is above the ellipsoid. Ellipsoid Height = GEOID Height + Orthometric Height. (AC 150/5300-18B)

**Feature** – A manmade or natural object that appears in the real world such as a building, runway, navigational aid or river. (AC 150/5300-18B)

**Feature Type** – A collection of all features of a given type such as all runways or all buildings. Feature Types are analogous to layers in many GIS applications and are also referred to as Entity Types and Feature Classes in other standards. (AC 150/5300-18B)

**Feature Instance** – A specific feature such as runway 10/28 at Baltimore Washington International Airport. (AC 150/5300-18B)

**First Return** – For a given emitted pulse, it is the first reflected signal that is detected by a 3D imaging system, time-of-flight type (TOF), for a given sampling position, that is, azimuth and elevation angle. (ASTM E 2544-09b)

**Fundamental Vertical Accuracy** – The fundamental vertical accuracy is the value by which vertical accuracy can be equitably assessed and compared among datasets. The fundamental vertical accuracy of a dataset must be determined with check points located only in open terrain where there is a very high probability that the sensor will have detected the ground surface. It is obtained utilizing standard tests for RMSE. (Refer to Consolidated and Supplemental Vertical Accuracies.) (NDEP, 2004)

**GEOID** – The theoretical surface of the earth that coincides everywhere with approximate mean sea-level. The GEOID is an equipotential surface to which, at every point, the plumb line is perpendicular. Because of local disturbances of gravity, the GEOID is irregular in shape. (AC 150/5300-18B)

**GEOID Height** – The distance, taken along a perpendicular to the reference ellipsoid, between the reference ellipsoid and the GEOID. The GEOID height is positive if the GEOID is above the reference ellipsoid. (GEOID height is negative for the conterminous United States). GEOID Height = Ellipsoidal Height - Orthometric Height. (AC 150/5300-18B)

**Independent Source of Higher Accuracy** – Data acquired independently of procedures to generate the dataset that is used to test the positional accuracy of a dataset. The independent source of higher accuracy shall be of the highest accuracy feasible and practicable to evaluate the accuracy of the dataset. (NDEP, 2004)

**Last Return** – For a given emitted pulse, it is the last reflected signal that is detected by a 3D imaging system, time-of-flight type (TOF), for a given sampling position, that is, azimuth and elevation angle. (ASTM E 2544-09b)

**Light Detection and Ranging (LIDAR)** – An instrument that measures distance to a reflecting object by emitting timed pulses of light and measuring the time between emission and reception of reflected pulses. The measured time interval is converted to distance. (NDEP, 2004)

**Local Control** – A control station or network of control stations in a local area used for referencing local surveys. Local control may or may not be tied to the National Spatial Reference System. (See Control Station) (AC 150/5300-18B)

**Metadata** – Information about the data itself such as source, accuracy, dates for which the data are valid, security classification, etc. Metadata is essential in helping users determine the extent on which they can rely on a given data item to make decisions. (AC 150/5300-18B)

**Multiple Returns** – For a given emitted pulse, a laser beam hitting multiple objects separated in range is split and multiple signals are returned and detected. (ASTM E 2544-09b)

**National Spatial Reference System (NSRS)** – A network of permanent survey monuments located throughout the United States with accurately determined positions (horizontal network) and/or elevations (vertical network). Gravity values, not always monumented, are also part of NSRS. Responsibility for establishing and maintaining NSRS rests with the National Geodetic Survey under the U.S. Department of Commerce. Current authority is contained in United States Code, Title 33, USC 883a as amended, and specifically defined by Executive Directive, Bureau of the Budget (now Office of Management and Budget) Circular No. A-16 Revised. (AC 150/5300-18B)

**Orthometric Height** – The distance taken along the plumb line between a point and the GEOID. Orthometric heights are positive if the point is above the GEOID. Orthometric Height = Ellipsoid Height - GEOID Height. (AC 150/5300-18B)

**Point Cloud** – A collection of data points in 3D space (frequently in the hundreds of thousands), for example as obtained using a 3D imaging system. (ASTM E 2544-09b)

**Positional Accuracy** –- The difference between a geospatial feature's displayed position and its actual position. Absolute positional accuracy is the difference between a geospatial feature's displayed position and its actual position on the face of the earth. Relative positional accuracy is the difference between a geospatial feature's displayed position and that of other geospatial features in the same data set. (AC 150/5300-18B)

**Post Spacing** – The smallest distance between two discrete points that can be explicitly represented in a gridded elevation dataset. It is important to note that features of a size equal to, or even greater than the post spacing, may not be detected or explicitly represented in a gridded model. For gridded elevation data the horizontal post spacing may be referenced as the cell size, the grid spacing, the posting interval, or the ground sample distance. Horizontal post spacing should be documented in the metadata file. (NDEP, 2004)

**Precision** – The smallest separation that can be represented by the method employed to make the positional statement which is the number of units or digits to which a measured or calculated value is expressed and used. (AC 150/5300-18B)

**Reference Ellipsoid** – A geometric figure comprising one component of a geodetic datum, usually determined by rotating an ellipse about its shorter (polar) axis, and used as a surface of reference for geodetic surveys. The reference ellipsoid closely approximates the dimensions of the GEOID. Certain ellipsoids fit the GEOID more closely for various areas of the earth. Elevations derived directly from satellite observations are relative to the ellipsoid and are called ellipsoid heights. (AC 150/5300-18B)

**Registration** – The process of determining and applying to two or more datasets the transformations that locate each dataset in a common coordinate system so that the datasets are aligned relative to each other. (ASTM E 2544-09b)

**Root mean square error (RMSE)** – The square root of the mean of squared errors for a sample. (NDEP, 2004)

**Second Order Moments ($\sigma_x^2$, $\sigma_y^2$)** – The second order moments of an irradiance distribution of a simple astigmatic laser beam at a given range, *z*, $\sigma_x^2(z)$, $\sigma_y^2(z)$, along the principle axes, *x* and *y*, are defined as:

$$\sigma_x^2(z) = \frac{\int_{-\infty}^{0}\int_{-\infty}^{0} I(x,y,z)(x-\bar{x})^2\,dxdy}{\int_{-\infty}^{0}\int_{-\infty}^{0} I(x,y,z)\,dxdy}$$

$$\sigma_y^2(z) = \frac{\int_{-\infty}^{0}\int_{-\infty}^{0} I(x,y,z)(y-\bar{y})^2\,dxdy}{\int_{-\infty}^{0}\int_{-\infty}^{0} I(x,y,z)\,dxdy}$$

where:

I(x,y,z) the irradiance or optical power per unit area at point (x,y,z),

$\bar{x}$ and $\bar{y}$ the coordinates of the centroid (also referred to as the first order moments) of the beam in the x y plane, respectively.

(ASTM E 2544-09b)

**Simple Astigmatic Beam** – A beam having non-circular power density distributions and whose principle axes retain constant orientation under free propagation. (ASTM E 2544- 09b)

**Supplemental Vertical Accuracy** – The result of a test of the accuracy of z-values over areas with ground cover categories or combinations of categories other than open terrain. Obtained utilizing the 95th percentile method, a supplemental vertical accuracy is always accompanied by a fundamental vertical accuracy. (Refer to Fundamental and Consolidated Vertical Accuracies.)

**Well-Defined Point** – A point that represents a feature for which the horizontal position is known to a high degree of accuracy and position with respect to the geodetic datum. (NDEP, 2004)

 

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