Pictometry LiDAR

Pictometry offers LiDAR datasets collected at several different point density and accuracy levels to suit a variety of mapping requirements. The following details Pictometry's data collection and processing methodology and techniques, all of which have been chosen so as to be fully compliant with FEMA and USGS standards. Additional deliverables to support verification of compliance, including detailed reporting and ground truth surveys may be required to achieve full compliance.

Data Capture

LiDAR data is collected while atmospheric conditions are such that the air between the aircraft and the ground is cloud and fog free and the ground is generally snow free. Pictometry captures LiDAR using an Optech ALTM Gemini LiDAR sensor or equivalent. Pictometry's LiDAR system is capable of recording surface elevation measurements at up to 167 kHz, and at vertical accuracies up to 5cm. For reference three typical operational configurations are shown below. Pictometry will operate the system in the manner prescribed and based upon the point density chosen. These capture parameters, in conjunction with the utilization of Pictometry's Trimble R8 and 5700 GPS receivers, enable production of accurate data to create any selected derivative products. Pictometry's data collection techniques and operational parameters have been chosen to be fully compliant with FEMA and USGS standards.

Operational Configurations

	Nominal Point Spacing		
Parameter	**1.0m**	**0.7m**	**0.5m**
Flight Altitude	1800m/5900ft	760m/2500ft	500m/1600ft
Point Density	1 point/m^2	2 points/m^2	4 points/m^2
Pulse Repetition Frequency	100kHz	70kHz	50kHz
Scan Angle (+/-)	16.9°	15.8°	10.1°
Scan Frequency	42.1Hz	56Hz	70.1Hz
Swath Width (raw)	1100m/3600ft	430m/1400ft	175m/475ft
Overlap	30%	30%	30%
Vertical Accuracy (bare earth)	15cm $RMSE_z$	9.25cm $RMSE_z$	9.25cm $RMSE_z$
	30cm NSSDA 95%	18.2cm NSSDA 95%	18.2cm NSSDA 95%
Horizontal Accuracy*	30cm, RMSE	20cm, RMSE	20cm, RMSE

	Nominal Point Spacing		
Parameter	**1.0m**	**0.7m**	**0.5m**
Contour Interval Supported	2ft	1ft	1ft
Returns	*Up to four per pulse*		
Intensity Records	*Recorded for each return*		
**theoretical value per manufacturer's specification*			

Data Processing

Once data has been captured, the GPS/INS data is post processed with the GPS data logged at the reference station using Applanix POSPac to generate a smoothed best-estimate trajectory (SBET). This trajectory is then applied to the raw laser data using Optech's Dash Map software package to generate the initial point cloud. During this phase, the system calibration data is also applied to provide corrections to the point cloud based on the specific characteristics of the laser scanner. Pictometry performs a full recalibration of its Gemini system approximately once every six months. In addition to this semi-annual calibration, Pictometry calculates fine corrections on a mission by mission basis using TerraMatch software, as described in the next step.

TerraSolid - Matching and Classification

After generation of the raw point cloud data in LAS format in Dash Map, the data is imported into the TerraSolid software suite (running under Bentley's MicroStation) for matching and classification. Upon import, the data is divided into tiles for the purpose of creating more manageable data. This tiling scheme may be specified in advance by the client, if desired. Once imported to TerraSolid, blocks of data containing overlapping flight lines are selected. The data in these blocks is analyzed by TerraMatch and adjustments to the roll, pitch, heading, and scale that minimize any data misalignment between the flight lines are computed. These adjustments are then applied to the entire mission's worth of data. Data across the mission is then manually reviewed to ensure proper alignment between flight lines has been achieved. This process is then repeated for each mission; once complete, intra-sortie alignment is verified. Ultimately, the data is checked against a set of ground control points to determine overall accuracy and may be shifted uniformly to best fit the control data.

Classification

During this phase, points are assigned to various classes per the ASPRS Standard LiDAR point class as set forth in LAS Specification v1.3 R10 published on July 14, 2009. Pictometry will utilize the Withheld bit to identify overlap points prior to initiation of classification. Noise points – generally low points and

atmospheric noise – will be identified and moved to class 7 as specified. Points representing the ground surface will be assigned to Class 2; classification of ground points is accomplished by application of a series of automatic filters followed by manual reviews to determine filter performance. A variety of filters may be utilized depending on the terrain types present in the project area, augmented by manual review and cleanup to remove outlying points.

Metadata

Pictometry develops and delivers FGDC compliant metadata at the project level in conjunction with its LiDAR data offering.

LiDAR Data Deliverables:

- LiDAR Point Cloud Data
  - Tiled* LAS v1.2/3 files including Return Number and Intensity attribute for each return
    - Duplicate points and 95% of outliers removed
  - Ground points classified via automated methods with manual review and clean up
    - 95% of vegetation features removed
    - 98% of buildings removed
  - Buildings and vegetation not classified separately
- Raw GPS/INS data and laser range files with supporting information
- FGDC compliant metadata
- Estimated Data Sizes (at 1.0m point spacing):
  - 10-12 GB per 100 square miles (approximate)

LiDAR Derived Terrain Products

Pictometry offers the following LiDAR derived terrain mapping products to facilitate broad based usage and democratization of LiDAR data.

DEM (Bare Earth)

ESRI Terrain

Pictometry will convert the Bare Earth classified data contained in the LAS files to ESRI Terrain data as a fundamental step toward deriving subsequent bare earth terrain products. Developing the data in this manner will significantly enhance the delivery of data to the Customer and provide maximum flexibility for future use, updates, and edits. **Standard Hydrographic Breaklines (described below) will be incorporated into all terrain deliverables.** Additional breaklines may be developed and incorporated into the terrain at any time.

Digital Elevation Models (DEMs)

The standard DEM deliverable will be assumed to have a 10-foot grid cell size unless otherwise specified by the customer. Pictometry will also develop a Hillshade from the DEM for visualization and cartographic mapping purposes.

Standard Hydrographic Breaklines

Breaklines are linear features that describe a change in the smoothness or continuity of a surface. As part of the baseline effort to create a DEM, Pictometry will develop limited 3D breaklines for water feature boundaries and wide rivers and incorporate those into the ESRI Terrain data prior to generating any derived products. Hydrographic breaklines will be delineated using the LiDAR data with elevation values assigned from the LiDAR data, using best available aerial photography and the National Hydrography Dataset (NHD) as references.

Water bodies will be defined for the purposes of this task as being larger than 5m across, or greater than one (1) acre. Breaklines delineating the edge of water will be created for all such water bodies. Breaklines will not be developed for streams less than 5m across, also referred to in NHD as “single line streams”.

The standard for water bodies in the USGS Specification is 100ft and two (2) acres respectively. “Hydro-flattening”, as defined in the USGS Specification, will be completed at a minimum on all water bodies meeting the USGS definition. This task is intended to meet or exceed the requirements for “Hydro-flattening” in the USGS Specification.

Polygons representing flat and level water bodies (ponds, lakes), a single elevation value will be assigned to the entire polygon and/or to every bank vertex. The entire water surface edge will be at or just below the immediately surrounding terrain. For streams and rivers, breaklines indicating flat and level bank-to-bank conditions (perpendicular to the apparent flow centerline) will be created, with the gradient along the bank to follow the immediately surrounding terrain. Monotonicity will be enforced on breaklines meeting the USGS Specification. Stream and river breaklines delineating the edge of water will stop at road crossings (i.e., culvert locations).

Bare earth LiDAR points that are within the design Nominal Point Spacing (NPS) of a breakline will be re-classified as “Ignored Ground” once the breaklines have been completed. The design NPS of a LiDAR collection is typically between 1 and 2 meters, but may be greater or less depending on the collection specifications of the project.

The identification and prioritization of additional breaklines beyond those minimally described here represents a wide range of expectations and detail depending on specific project/customer needs and intended uses. Most customized uses of breaklines are appropriate for project specific purposes, such as

hydraulic modeling, construction site design or transportation engineering. As such, additional breakline development options are offered below. Additional detailed breaklines can be developed and incorporated into the terrain data at any time.

Deliverables:
Collection-wide point data (bare earth only) in ESRI multi-point format
Collection-wide Terrain Data Model (bare earth) in ArcGIS TERRAIN format
Collection-wide Digital Elevation Model (bare earth) in ArcGIS GRID format
Collection-wide polyline files in ESRI Polyline Feature Class format
Collection-wide Hillshade of the Bare earth DEM in ArcGIS format

Contours – available with DEM

The range of available algorithms can result in significant differences in cartographic output quality for the generation of topographic contours. Some methods more accurately represent the point data, but result in a more angular and less cartographically pleasing output. Other methods will smooth the data to varying degrees but produce a much higher quality cartographic output. The customer will be given options, based on demo data, for having their collection area contours created from smoothed data or not-smoothed data.

This task will result in vector (line) data and as such, tiling the data will be required because the vector files can be quite large. The output tiling scheme will correspond to the LiDAR tiles unless the customer requests a different tiling scheme in advance. Final tiled vector data will be seamless and free of edge effects. Pictometry will establish elevation attributes to each contour line and identify 10, 20, and 50 ft. index contours unless otherwise specified by the Customer.

Deliverables:
Tiled 1-foot or 2-foot* contour files in ESRI Polyline Feature Class format. (*NOTE: Contours will be created at maximum resolution supported by the collection as specified in Section 1.)

Breaklines

Additional Hydrographic and Slope Breaklines

Pictometry will generate additional detailed hydrographic vector data from available digital imagery, elevation and vector GIS data. The reference data for this mapping effort will continue to be the National Hydrography Dataset (NHD). The primary method for developing these data will be to map the location of the breaklines from the LiDAR data directly using best available aerial photography as a reference for extraction of surface features. To the extent that the location or the elevation of features cannot be adequately resolved, stereo-photogrammetric methods may be used.

Additional hydrographic breaklines will be developed as follows:

Stream Centerlines:	For small streams <5m identifiable from the LiDAR data and/or the Orthophotography. The reference data for these channels are commonly referred to as "single line streams" in NHD.
Edge of Water:	For streams with identifiable water >5m across Note: the edge of the water may NOT be synonymous with the edge of the stream channel depending on seasonal flow conditions in the stream.
Edge of Channel:	For channels >5m across independent of the existence of visible water Note: the edge of the channel is synonymous with the bottom of the stream bank.
Top of Bank:	For all banks with clearly definable morphology 2 meters higher than the Edge of Channel.

As such, it is possible for a stream segment to have anywhere from one to six unique breaklines representing the morphology of the stream. All stream center lines and edge of water lines will be tested for monotonicity (continuous downward slope).

The level and width of water within a stream channel may vary considerably throughout the year and can significantly impact breakline vector placement as well as point classification. It should be expected that vectors delineating water may differ from vectors indicating the top and/or bottom of the stream bank. Because of temporal variations in hydrologic conditions and water levels, it should be expected that the shoreline edges associated with mean-water, low flow or other hydrologic recurrence interval may vary from those mapped by this effort. In addition, Stream Centerlines will be derived for small streams only, and will not propagate through all water bodies as part of a linear hydrologic network. Development of a stream centerline hydrologic network is considered to be an additional task.

In addition to delineating stream morphology, breaklines that delineate sharp breaks in slope on key terrain may affect the accuracy or representation of the derived surface, and the quality of resulting contours. As part of this breakline effort, Pictometry will develop slope breaklines across the project area in addition to those described for streams above. Surface roughness and slope change analysis will be used to indicate places where breaklines are warranted, so that breaklines are extracted in places where real breaks exist in the smoothness of the terrain. Key terrain includes natural features such as ridges, valleys, bluffs, cliffs, and the tops of stream banks not otherwise included with hydrographic breaklines. Key terrain also includes man-made features such as dams, retaining walls or road cut structures or embankments that affect the slope of the overall ground surface but might not otherwise be included with transportation breaklines.

Deliverable:
Collection wide polyline files in ESRI Polyline Feature Class format.

Breaklines for Transportation Features

Pictometry will generate transportation related planimetric data representing the edge of pavement for all road features using best available imagery, elevation and vector GIS data. The data will be used as breaklines to further enforce these features in the DEM. Reference data for this will be best available public domain street centerline data and will be captured at a scale of 1:500 or better.

Deliverables:

Collection wide polyline files in ESRI Polyline Feature Class format.

DSM (Reflective Surface)

Pictometry will convert the data contained in the LAS files to a raster based Digital Surface Model (DSM) representing a "first surface" detected by the sensor. This first surface is represented by both bare ground in open terrain, as well as the tops of trees and buildings in areas with significant non-ground features. The elevation value of each cell in the raster dataset will represent the highest elevation value of points that fall within that cell. This surface model will not include the development or use of additional breaklines beyond that which are included with the bare earth data. Included with each DSM will be a Hillshade for visualization and cartographic purposes.

Pictometry will also calculate and deliver a "normalized" Digital Surface Model (nDSM) where the elevation value of each cell represents the height above ground of the highest point within that cell. For both surface models, cells with no points will be interpolated based on the averaged values of nearby cells (nearest neighbor).

Pictometry recommends including some cautionary language to all potential users of DSM data due to some of the unique characteristics of such a dataset. In some areas, a first surface model will result in objects that appear to contain a solid volume, so caution should be used when interpreting the data. Pictometry does not recommend the use of image draping on first surface DSM models as the image stretching can be aesthetically undesirable.

Deliverable:
Collection-wide DSM and nDSM in ArcGIS GRID format with 10 foot grid cell size unless otherwise specified by the Customer.

Interpretive Mapping Products

Pictometry offers the following ancillary datasets to aid in interpretation of LiDAR data and other derived datasets.

Void Area Mapping

Pictometry anticipates that there will be a range of void areas on the bare earth data as a result of non-ground feature removal or absorption by water. Pictometry will derive void area polygons from the Bare Earth point data. This ancillary deliverable is particularly useful for the Customer to have as a legacy of the collection to better understand and articulate the limitations and assumptions (i.e., interpolation) that are inherent in the derived data products. In accordance with both FEMA guidelines and the USGS Specifications, voids areas in bare earth data of ≤10m GRID ($100m^2$) and of ≤8m GRID ($64m^2$) in first return data will be mapped.

FEMA guidelines indicate that void areas greater than one (1) acre occurring in the floodplains may require additional ground survey, independent of the overall collection statistics. As such Pictometry will attribute the land cover for Bare Earth void polygons larger than one acre.

Deliverable:
Collection-wide Void Area polygon data in ESRI Polygon Feature Class format.

Slope Data

Pictometry will derive percent rise and degree slope GRIDs from the DEM data developed above. The extent will be the same as the source DEM with values for slope.

Deliverable:
Slope data in ArcGIS GRID format

Intensity Data

Pictometry will develop intensity grids from the data contained in the LAS files. This data is particularly useful for customers to use in urban planning and hydrologic applications such as evaluating land cover types, impervious surface areas and changes in the landscape. The data will be tiled to the original LiDAR tiles, in ESRI GRID format with a grid cell size corresponding to the average post spacing of the all points LiDAR data unless otherwise specified by the Customer. Pictometry will interpolate across voids unless the customer specifies otherwise. A raster catalog will also be included of all the tiles.

Deliverable:
Tiled Intensity data in ArcGIS Grid format unless otherwise specified.
ESRI raster catalog of all the tiles