PAMAP LiDAR PROGRAM

Department of Conservation & Natural Resources

LiDAR Acquisition Report

For

Program Years 2006, 2007 & 2008

Produced By:

2670 Wilhite Drive
Lexington, KY 40503

Under Contract to:

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Mount Laurel, NJ 08054

May, 2010

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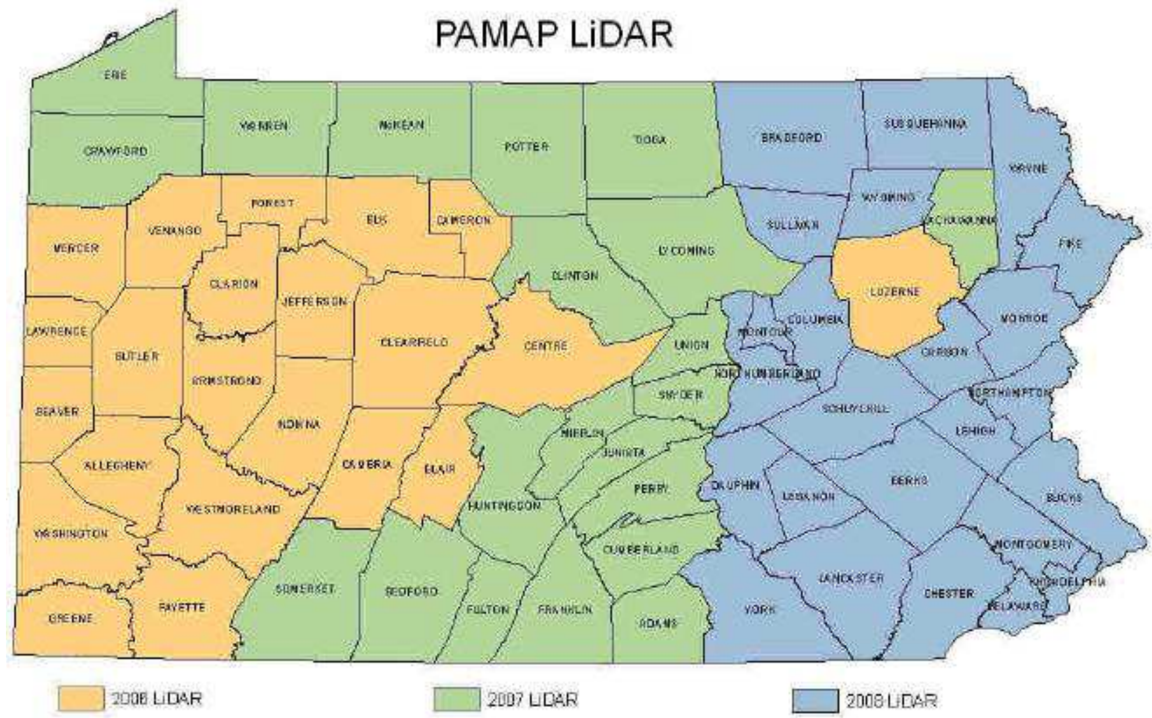
SECTION 1

OVERVIEW

SECTION 1: OVERVIEW

The PAMAP Program conducted project to collect and process high resolution LiDAR elevation data for the entire state. Pennsylvania is one of the first states in the nation to complete collection of this level of elevation data for the entire state. In winter/spring 2006, the PAMAP Program began the project with the capture of LiDAR for 21 counties in the western part of the state, along with Luzerne County. LiDAR was acquired for an additional 21 counties in the winter/spring of 2007. Acquisition of LiDAR in the spring of 2008 covered 25 additional counties in the eastern third of Pennsylvania. The collection progress over the three year period is shown below.



Working as a subcontractor to the PAMAP Prime Consultant, BAE Systems, Mount Laurel, NJ, Photo Science has been the lead PAMAP data acquisition firm supporting both the imagery and LiDAR program since 2005.

The LiDAR data acquired by Photo Science in support of the Program is primarily being used to produce an accurate and high-resolution bare earth model of Pennsylvania. One of the primary uses of the bare earth model is to support floodplain mapping and flood control projects. The LiDAR data is collected and processed to generally meet specifications called for in FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners. The data is collected with a 1.4-meter average point spacing (2-meter maximum) with a bare earth surface vertical accuracy of 18.5-centimeters RMSE. Data is in tile form using the PAMAP 10,000-foot tile index. All products are in the public domain.

The data products include:

- LiDAR Point Cloud – the LiDAR points are distributed in the binary LAS format. Each point is attributed for intensity, classification, etc. according to the LAS standard and PAMAP specifications.
- Digital Elevation Model – a 3.2-foot pixel (1-meter equivalent) raster GeoTIFF Digital Elevation Model (DEM).
- Contours – a 3D shape file of 2-foot contours is provided for each tile.
- Break lines – a 3D shape file of break lines is provided for each tile.

Photo Science's Role

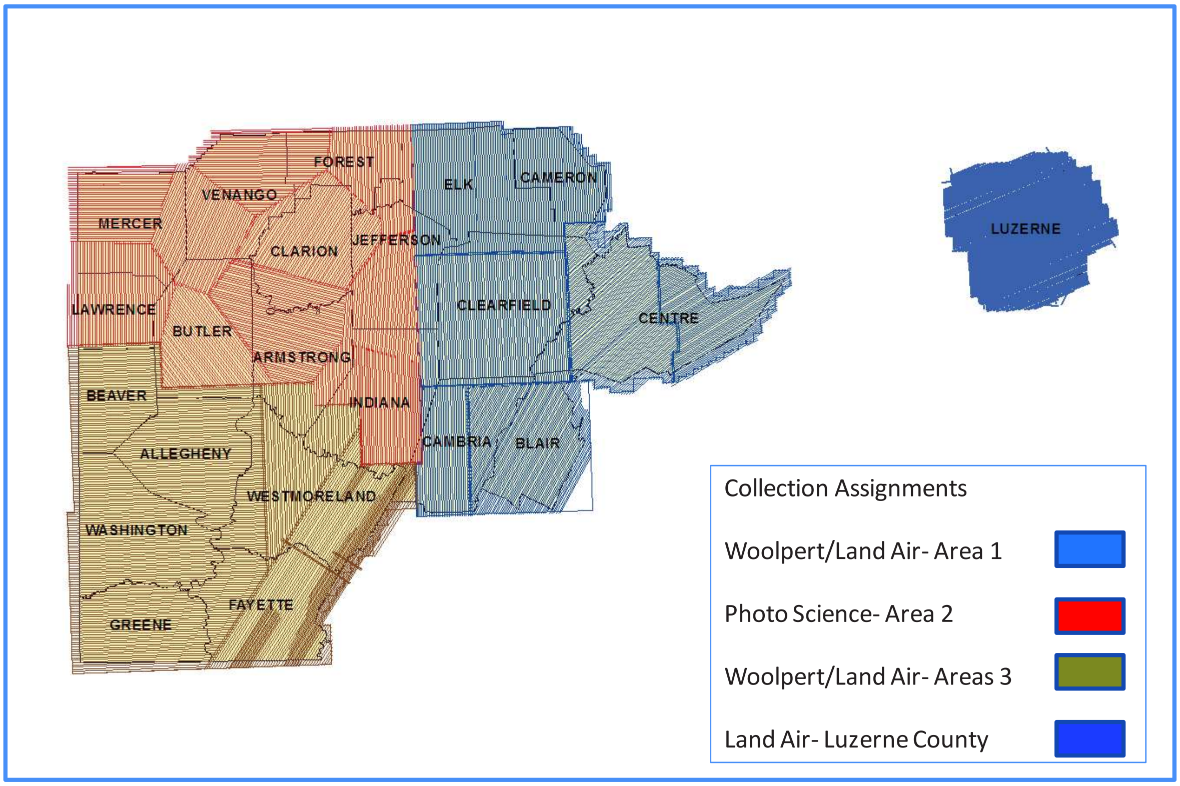
Coordinating other leading LiDAR data collection firms, Photo Science has provided airborne topographic LiDAR collection and post processing services to BAE Systems in support of PAMAP Program years in 2006, 2007 and 2008. This LiDAR data has been used to develop the terrain surface and derivative datasets identified above as well to support the orthophoto rectification of PAMAP imagery collected in each of the same years.

The following LiDAR providers directly supported the acquisition and processing activities in each of the three program years. Collection assignments are shown for each year in the provided diagrams.

PAMAP 2006

- Photo Science, Lexington, KY
- Woolpert Inc., Dayton, OH - sub consultant to Photo Science
- Land Air, Peach Tree, GA (now part of Northrop Grumman/3001) – sub consultant to both Photo Science for the Luzerne County Area and Woolpert

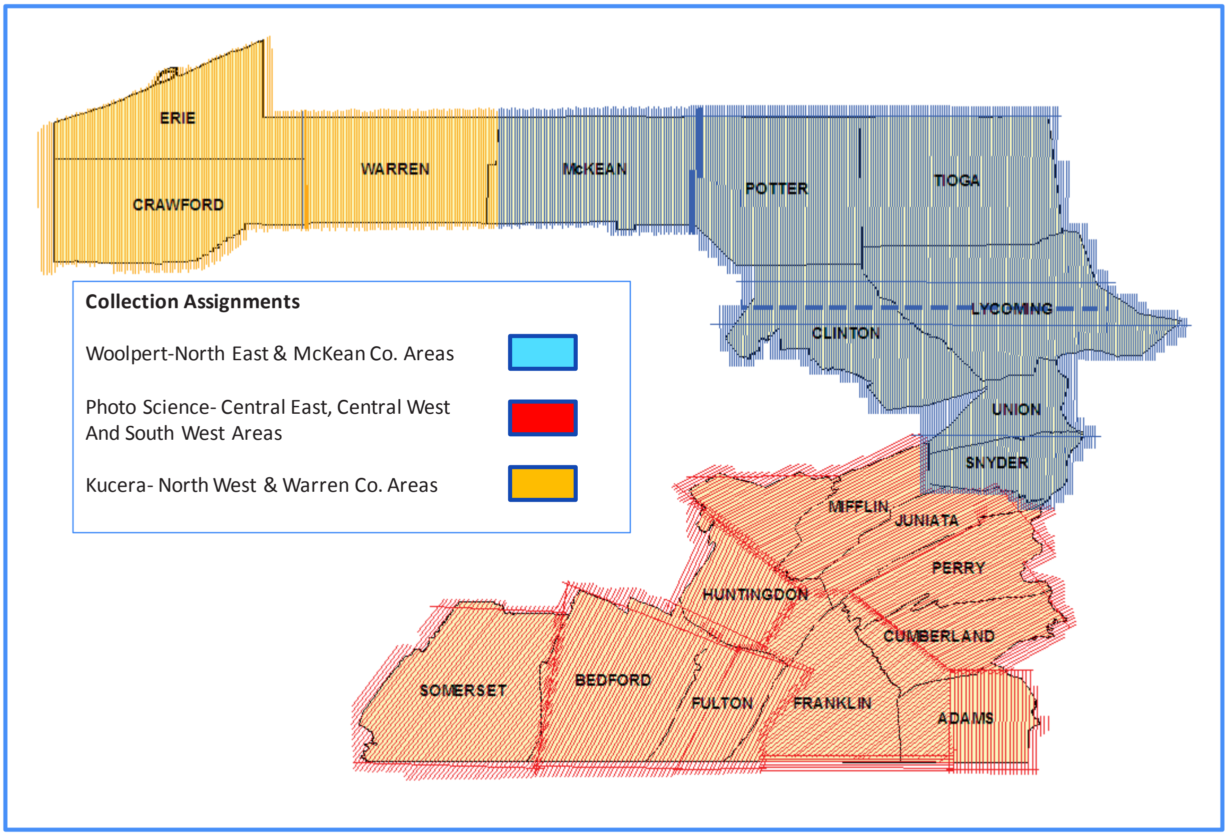
PAMAP 2006 LIDAR Collection Area



PAMAP 2007

- Photo Science, Lexington, KY
- Woolpert Inc., Dayton, OH - sub consultant to Photo Science
- Kucera International, Willoughby, OH – sub consultant to Photo Science

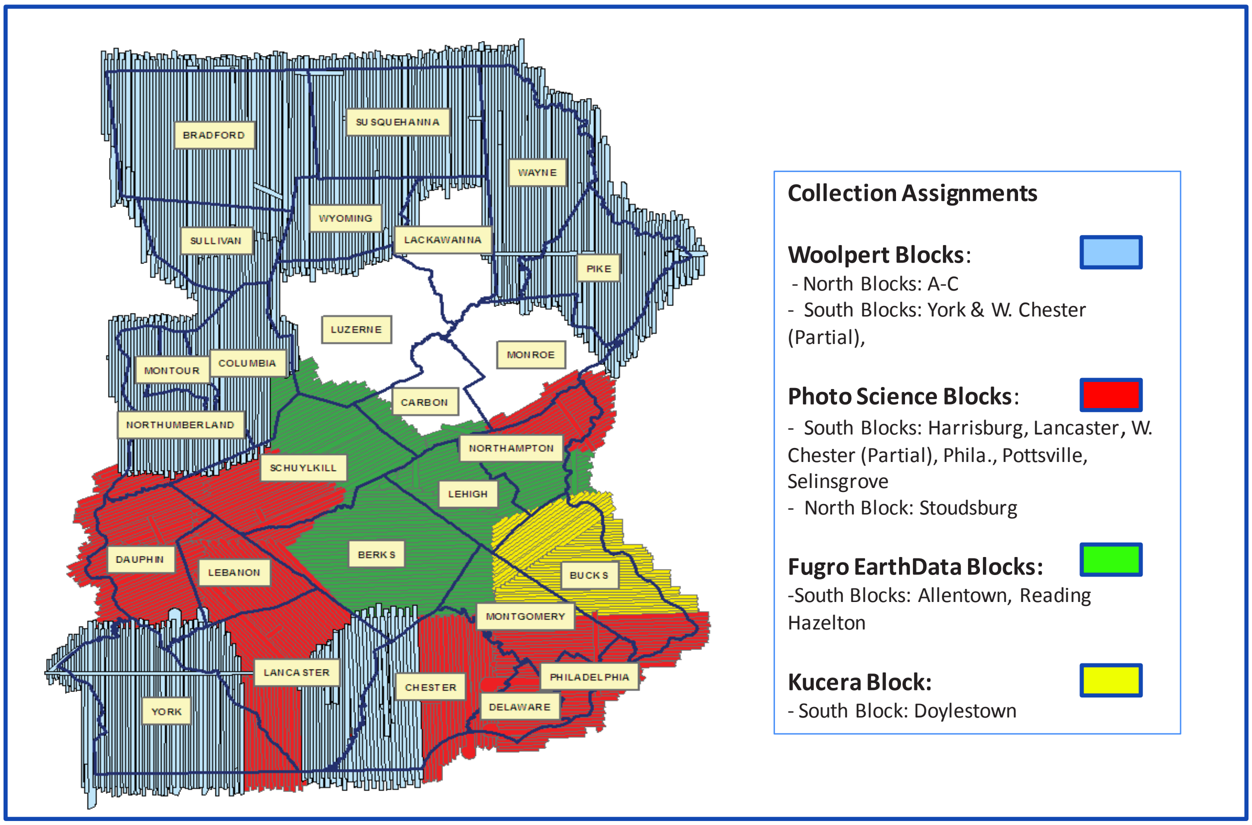
PAMAP 2007 LIDAR Collection Area



PAMAP 2008

- Photo Science, Lexington, KY
- Woolpert Inc., Dayton, OH - sub consultant to Photo Science
- Kucera International, Willoughby, OH – sub consultant to Photo Science
- Fugro EarthData, Fredrick, MD- sub consultant to Photo Science

PAMAP 2008 LIDAR Collection Area



Report Contents

This report contains a review of the project requirements and detailed information for LiDAR data acquisition, processing and quality control performed by Photo Science (and its sub consultants) including:

- Documentation specifying altitude, airspeed, scan angle, scan rate, LiDAR pulse rates, and other flight and equipment information deemed appropriate
- A LiDAR Data Acquisition Report
- A LiDAR Data Processing Report
- A System Calibration Report (Sample)
- Flight & Base Station Logs

Please note that Photo Science primary LiDAR sub consultant, Woolpert Inc., submitted separate (but similar) reports directly to BAE Systems for LiDAR acquisition and post processing work assignments covering each of the three program years (2006-2008).

Project Requirements

General standards for the LiDAR mission include:

- High density LiDAR data acquisition within the project limits at a sufficient altitude and density to support digital terrain model (DTM) development for 2-foot contours with a vertical accuracy of 18.5 cm RMSE for the bare earth surface & a vertical accuracy in vegetated areas of 37 cm RMSE.

- Avoidance of inclement weather for all flight missions as well as ground conditions that do not allow adequate and/or accurate laser returns (Snow, extremely high water etc.).

- Planned flight paths which provide satisfactory coverage of the study area, including both parallel and enough cross flight lines to allow for proper quality control.

- Documentation of flight mission date, time, flight altitude, airspeed, scan angle, scan rate, laser pulse rates and other information deemed pertinent.

SECTION 2

LiDAR DATA ACQUISITION

SECTION 2: LIDAR DATA ACQUISITION

This section provides an overview of the general LiDAR acquisition methodology employed by Photo Science and its subcontractors on the LiDAR portion of the PAMAP Program.

The following table provides the planned LiDAR system collection parameters that were utilized by Photo Science and its sub contractors for the PAMAP Project across all three project years. Actual parameter values fluctuate depending on sensor/aircraft configuration, terrain, ground conditions/cover, weather conditions and air space access. Please refer to the flight logs in Appendix A for actual parameters for each mission. Woolpert's parameters are detailed in their LiDAR Acquisition Reports that were separately delivered to BAE Systems for each of the three project years.

2006 Project

LiDAR Collection Parameter	Photo Science	Woolpert*	Land Air
Flying Altitude, Feet (AMSL)	6000	5500	5400
Airspeed (Knots)	128	130	130
Scan Angle, Degrees (FOV)	42	42	42
Scan Rate (Hz)	29	26	26
Pulse Rate (Hz)	54	41	41
Pulse Mode (Returns)	4	2/4	4
Ave Point Spacing (meters^2)	1.5	1.4	1.4

* Two different ALS sensor models utilized

2007 Project

LiDAR Collection Parameter	Photo Science	Woolpert*	Kucera
Flying Altitude, Feet (AMSL)	6000	5500/7000	6000
Airspeed (Knots)	128	130	140
Scan Angle, Degrees (FOV)	42	42	44
Scan Rate (Hz)	31	26/27	31
Pulse Rate (Hz)	57	41/54	56
Pulse Mode (Returns)	4	2/4	4
Ave Point Spacing (meters^2)	1.5	1.4	1.3

* Two different ALS sensor models utilized

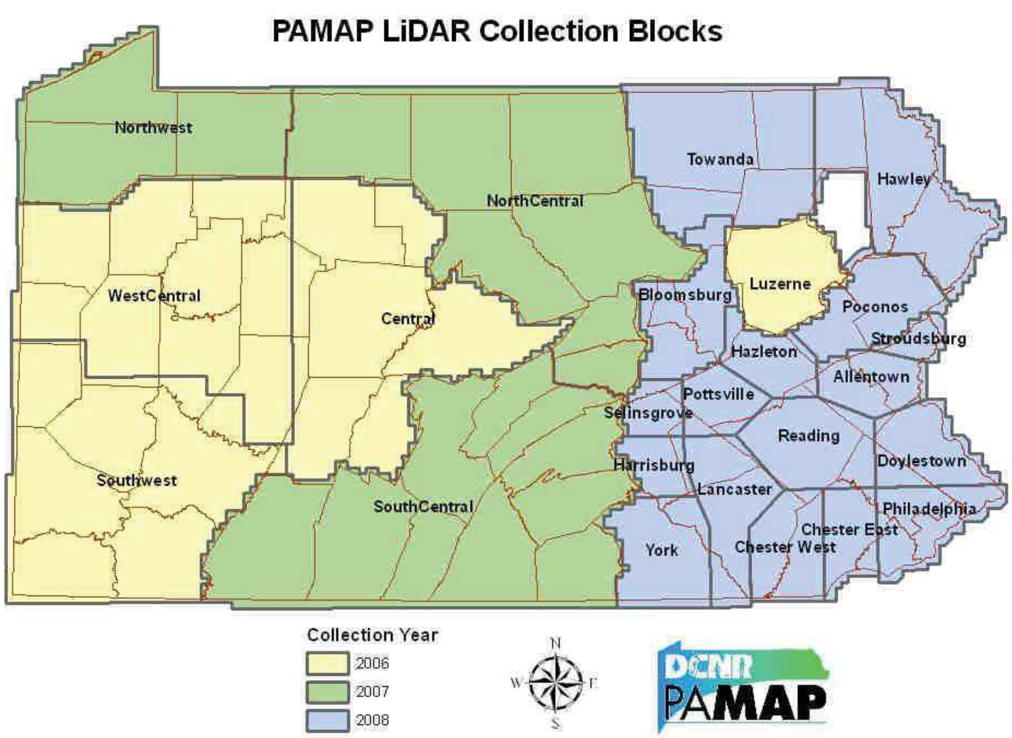
2008 Project

LiDAR Collection Parameter	Photo Science	Woolpert*	Kucera	Fugro Earthdata
Flying Altitude, Feet (AMSL)	7500	5500/7000	6000	8000
Airspeed (Knots)	120	130/125	130	160
Scan Angle, Degrees (FOV)	42	40/42	45	42
Scan Rate (Hz)	26	25/27	28	35
Pulse Rate (Hz)	53	41/53	52	93
Pulse Mode (Returns)	4	2/3/4	4	4
Ave Point Spacing (meters^2)	1.4	1.4	1.4	1.3

* Two different ALS sensor models utilized

LiDAR Overview

Photo Science conducted airborne topographic LiDAR surveys to support the production of a DEM for orthophoto rectification as well as 2-foot contour intervals. The LiDAR data was acquired for the entire State of Pennsylvania over a three year period (2006-2008) based on the collection blocks shown below.



LiDAR Mission

All LiDAR acquisition utilized Leica LiDAR ALS Systems with maximum pulse rates ranging from 40kHz to 150kHz. Leica Aeroplans detailing each LiDAR Provider's proposed collection parameters were previously submitted to BAE Systems for each project year along with flight line shape files and base stationing as part of the preflight planning deliverables. Additionally, specific details about the ALS systems are included in Section 5 of this report.

The airborne GPS (ABGPS) base stations supporting the LiDAR acquisition consisted of the Pennsylvania CORS system as well as supplemental bases set up by the flight and survey crews at various airports and control points in Pennsylvania. Dual Frequency data was logged continuously for the duration of each LiDAR flight mission at a one-second sampling rate or better. LiDAR collection was planned to try to remain within approximately 25 miles of base stations wherever possible.

The 2006-2008 flight line plans (shown below) for LiDAR acquisition consisted of parallel flights in north-south directions or as dictated by the terrain for maximum efficiency across the project site. The following is a breakdown of the number of approximate flight lines and flight line miles per project year.

PAMAP 2006

Areas 1, 2 & 3

- 1,132 flight lines
- 32,956 flight line miles

Luzerne County

- 84 flight lines
- 2,064 flight line miles

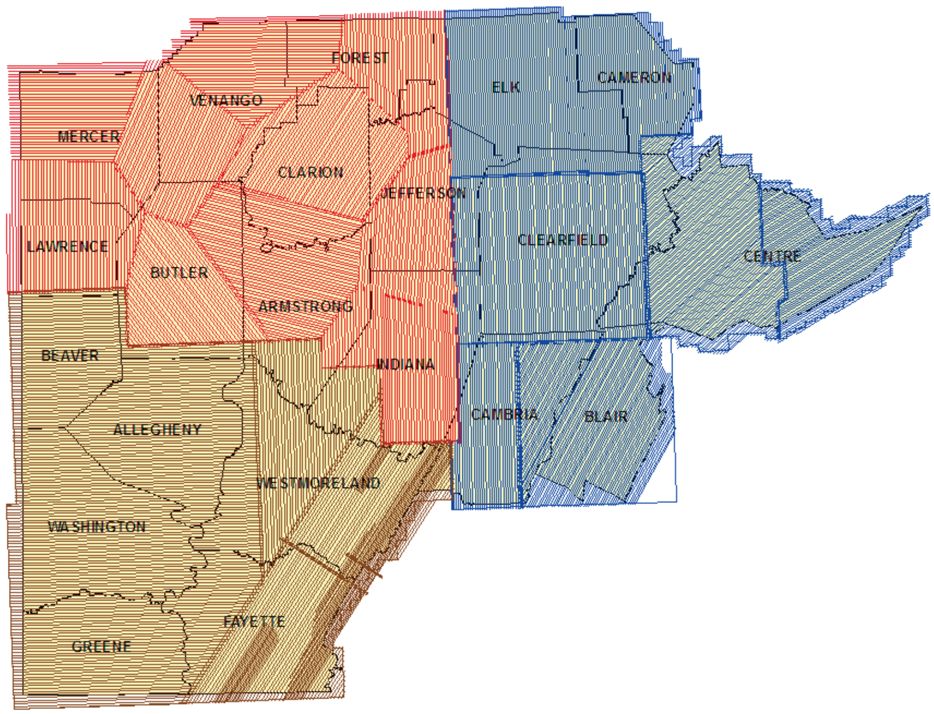
PAMAP 2007- All Areas

- 1,275 flight lines
- 34,216 flight line miles

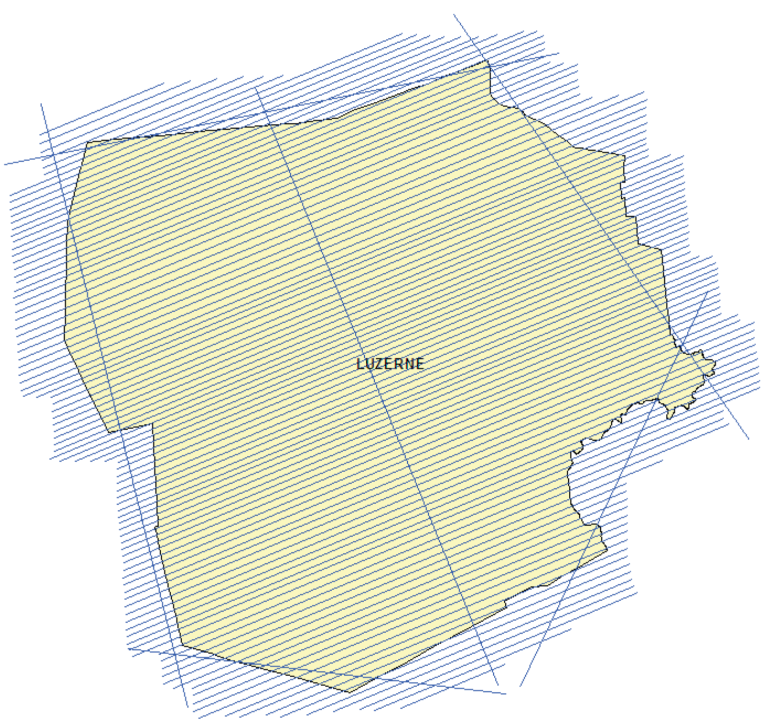
PAMAP 2008- All Areas

- 900 flight lines
- 22,303 flight line miles

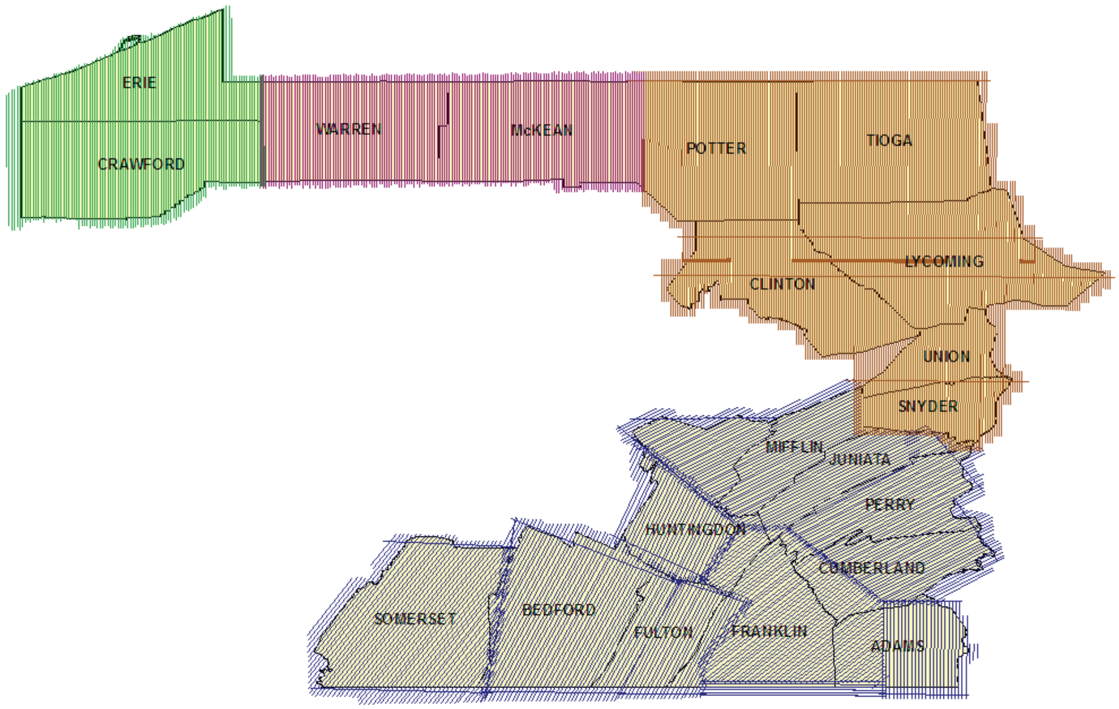
2006 Flight Plan



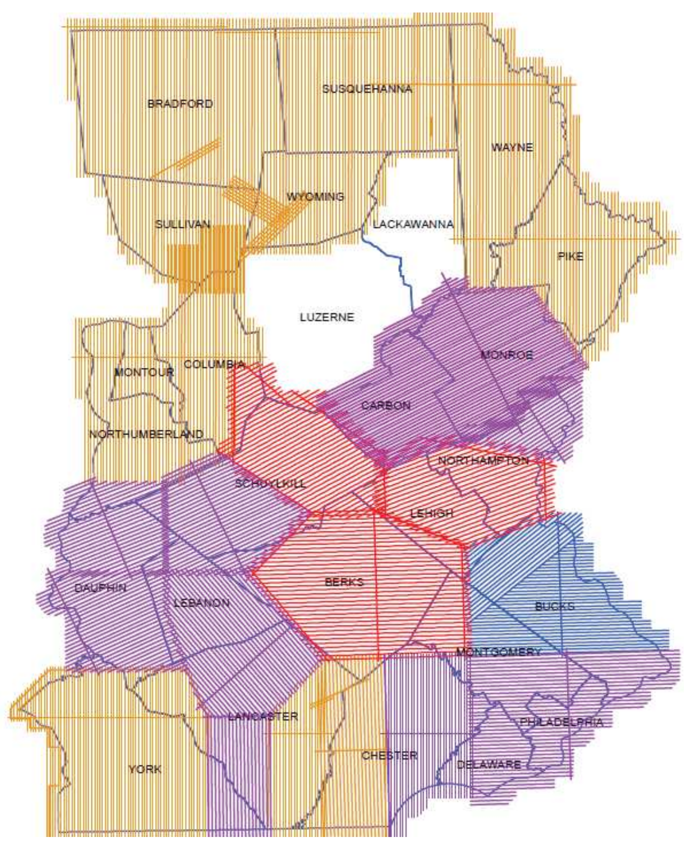
Luzerne County-2006



2007 Flight Plan



2008 Flight Plan



Data collected during the day (or night) was quality checked in the field by the collection crews to assure that here are no gaps or issues with data integrity. This is accomplished in order to develop a final data set before the equipment and crews leave the area. Generally we are able to catch 100% of the anomalies, but occasionally there maybe issues that surface in the final processing that do require a return to an area. Photo Science had no data void issues for the 2006 or the 2008 collection areas. However, 2006 reflights were needed due to data voids in the Woolpert 2006 collection area. These were accomplished in the fall/winter of 2006/2007. Additionally, Photo Science did have some minor data anomalies and data void issues in 2007 that were picked up early during the 2008 season. All initial and re-collected LiDAR data was processed to the degree necessary to ensure that complete datasets were delivered in each of the three project years.

LiDAR Statistical Data

The general LiDAR acquisition parameters utilized in the PAMAP program are shown below in the sample Aeroplan. . Leica Aeroplans detailing each LiDAR Provider's proposed collection parameters were previously submitted to BAE Systems for each project year along with flight line shape files as part of the preflight planning deliverables.

Specific to Photo Science, two systems were utilized; one an upgraded 150 MHz system and the other a 50 kHz System upgraded to 150 kHz Collection parameters for the two required different settings to collect the data to the PAMAP specification required. Photo Science and its sub contractors used these same general parameters for collection for all three years of collection (2006, 2007, and 2008). This helped assure that all data was collected to meet the final Specification.

Sample: Typical Aeroplan

AeroPlan Mission Planning for ALS Airborne Laser Scanners
Originator: Roth
Filename: AEROPLAN_Ver1_28C_ALS50-II_temp_060820.xls

SCANSET1064.xls

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FOR SHAPE / COLOR KEY, SEE BOX AT RIGHT

Scanner Setup

Commanded FOV (full angle)	***degrees***	45.00		
Scan FOV (full angle)	radians	0.79		
Scan FOV (half angle)	degrees	22.50		
Scan FOV (half angle)	radians	0.39		
Terrain Elevation AMSL (minimum in survey area)	meters	275.00	902.22	feet
Terrain Elevation AMSL (maximum in survey area)	meters	700.00	2296.56	feet
Nominal Flying Height Above Minimum Terrain Elevation	meters	2012.00	6600.97	feet
Nominal Flying Altitude AMSL	meters	2287.00	7503.19	feet
Airspeed	knots	120.00	61.73	meters/sec
Range/Intensity Mode (1, 2, 3, 4)		4.00		
Max Laser Pulse Rate	Hz	56300.00		
Laser Pulse Rate Used	Hz	53000.00	***4.24***	watts avg
System Controller Firmware (<V2.07, V2.07+)		V2.07+		
Laser Power Class (3=3W, 4=4W, LC50, XHR)		LC50		
Receiver Aperture Stop (45, 60, 65, 75, LM, ALS50)	degrees	ALS50		
Scan Rate	Hz	25.50		
Max Scan Rate (ALS50 Phase I+ / Phase II upgrade)	Hz	34.10		

Resulting Scan Pattern

			1.00	Spacing factor (Along track / Cr
Full Swath Width (nominal flying height above lowest terrain elevation)	***meters***	***1666.80***	***5468.42***	***feet***
Max Cross Track Spacing (occurs @ nadir)	meters	2.42	7.93	feet
Max Along Track Spacing (occurs @ FOV edge)	meters	2.42	7.94	feet
Cross Track / Along Track Ratio		1.00		
Illuminated Footprint Diameter (@ 1.e^2 energy)	meters	0.46	1.50	feet
Point Density (average)	pts/meter^2	0.52	0.05	pts/ft^2
Point Density (@ nadir)	pts/meter^2	0.34		
Area / Point (average)	meters^2	1.94	20.90	ft^2
Average Point Spacing	meters	1.39	4.57	ft

Required Attenuator or Percent Max Output

Minimum Attenuation Required or % output for ANSI Z136.1 (binoculars)	OD	0.11		
Minimum Attenuation Required or % output for ANSI Z136.1 (naked eye)	OD	0.00	14.00	Max SNR
Equivalent Attenuator Selection Used	OD	0.23	14.00	Average SNR
Optical Output Factor (for reference only)		0.59		
Recommended Laser Current	percent	65%		

Range Gate Settings

Nominal Maximum Slant Range	meters	2204.83
Recommended Range Gate "MIN" Setting (incl. roll, nav allow.)	meters	1560.00
Minimum Value for Range Gate "MAX" Setting	meters	960.00
Recommended Range Gate "MAX" Setting (incl. roll, nav allow.)	meters	2232.00

Estimated SNR for Diffuse Targets - "full field"

Surface Reflectivity		0.10
Nadir		14.71
FOV Edge		13.29

Estimated SNR for Diffuse Targets - "power line"

Line Diameter	millimeters	0.00
Line Reflectivity		0.30
Nadir (best case, with line centered in laser footprint)		0.00
FOV Edge (best case, with line centered in laser footprint)		0.00

LIDAR Flight Line Spacing (based on flying height above highest terrain elevation)

Roll Allowance (each side of nadir, 1 for roll-stabilized systems)	degrees	1.00		
Roll Allowance (each side of nadir)	radians	0.02		
Navigation Tolerance (above/below planned elev'n)	meters	25.00	82.02	feet
Swath Width After Roll All, El Nav Tol, Terr Variation	meters	1230.58	4037.27	feet
Navigation Tolerance (each side of planned line)	meters	25.00	82.02	feet
Line Spacing (for complete coverage, after roll/nav allowances)	***meters***	***1180.58***	***3873.23***	***feet***
Side Overlap (based on total swath width)	***percent***	***29.17***		
Coverage Rate (based on max line spacing)	km^2 per hr	262.37	101.30	mi^2 per hr

Resulting Accuracy Estimates (1 sigma)

Assumed GPS Error	meters	0.11	
		Nadir	FOV Edge
Estimated Cross-Track Error	meters	0.22	0.25
Estimated Along-Track Error	meters	0.21	0.24
Estimated Height Error	meters	0.13	0.15
Estimated Cross-Track Error	feet	0.72	0.81
Estimated Along-Track Error	feet	0.69	0.79
Estimated Height Error	feet	0.43	0.50

SECTION 3

PDOP INFORMATION

SECTION 3: PDOP INFORMATION

PDOP, the Positional Dilution of Precision, is a factor that describes the effects of satellite geometry on the accuracy of the airborne GPS solution. The geometric distribution of the satellites is measured relative to the locations of the receivers on the ground and in the aircraft. PDOP can be computed in advance, based on the approximate receiver locations and the predicted location of the satellite, which is called the satellite ephemeris.

Low PDOP numbers are preferable; the higher the PDOP number, the weaker the geometric quality of solution between the satellite, aircraft and reference receivers.

For the PAMAP LiDAR Program, Photo Science and its sub consultants ran prediction programs to determine times of PDOP before each mission (these are indicated on the Logs for each mission) to maintain a final PDOP of 4.0 or less during all LiDAR acquisition missions. Additionally PDOP was monitored during flights as the satellite geometry and the resultant PDOP levels are dynamic, changing with the position of the aircraft. Occasionally, one satellite in the network will drop below the horizon, breaking its connection to the receiver, and the PDOP level will spike above 4.0 momentarily. Small deviations of this type are accounted for during post-processing of the data through the use of Kalman filtering. If PDOP in the aircraft rises above 4.0 for a significant time period, the survey is usually stopped until the geometry improves.

SECTION 4

DATA PROCESSING AND QUALITY CONTROL

SECTION 4: DATA PROCESSING AND QUALITY CONTROL

LiDAR Data Processing

Photo Science and its sub consultants performed all initial post processing of the 2006, 2007 and 2008 LiDAR point clouds to an unclassified .LAS format. In conjunction with Woolpert and BAE Systems, Photo Science also performed initial bare earth classification for large portions of the datasets in each of the three project years. Lastly, Photo Science worked with BAE Systems to provide additional LiDAR “finishing” services to produce the final LiDAR and derivative elevation datasets identified in Section 1 in all three project years. This last area of “finishing” services provided by Photo Science has not been addressed in this report.

Initial Post Processing

In the initial post processing effort Photo Science employed GPS differential processing and Kalman filtering techniques to derive an aircraft trajectory solution at 1-second intervals for each base station within the project limits. Statistics for each solution (base station) were generated and studied for quality. The goal for each solution is to have:

- maintained satellite lock throughout the session
- position standard deviation of less than 5 centimeters
- low ionospheric noise
- few or no cycle slips
- a fixed integer ambiguity solution throughout the trajectory
- a maximum number of satellites for a given constellation
- a low (4.0 or less) Position Dilution of Precision (PDOP)

When the calibration, data acquisition, and GPS processing phases were complete, the formal data reduction process began. Photo Science LiDAR specialists:

- Studied individual flight lines and how these lines match adjacent flight lines to ensure the accuracy meets expectations.

- Identified and removed systematic error locally (by flight) which is not possible if the lines are combined into a block. This is sometimes the case when a satellite loss of lock occurs during a flight and the GPS solution fixes on the wrong integer ambiguity.

- Adjusted any small residual error (due to system noise) between flight lines and across all flight lines to survey ground control (or existing mapping if available).

- Clipped the overlap region of each flight line to obtain a single homogenous coverage across the project area. This eliminated redundant, overlapping point data that could overwhelm terrain modeling software packages.

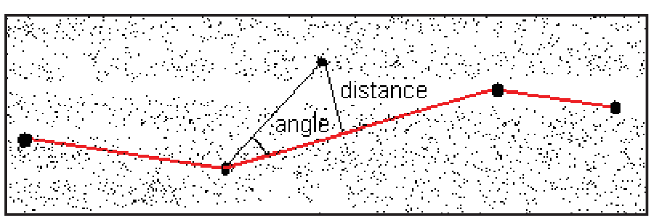
- Processed individual flight lines to derive “Point Cloud.”

Given the airborne GPS aircraft trajectory and the raw LiDAR data subdivided by flight lines, we used manufacturer software to reduce raw information to a LiDAR point cloud on the ground. Photo Science utilized proprietary software to generate parameter files, allowing the manufacturer’s software to process a block; this allowed for the batch processing any number of flight lines. As part of this process, outliers in the data are removed. Typical outlying data points are a result of returns from clouds.

Automated Bare Earth Classification

One initial post processing was completed, initial bare earth classification steps included:

- Classifying the point cloud data into ground and non-ground points
- The classification algorithm classifies ground points by iteratively building a triangulated surface model. The routine started by selecting some local low points as sure hits on the ground then built an initial Triangulated Irregular Network (TIN) from selected low points. The routine then started developing the ground model upward by iteratively adding new laser points to it. Each added point made the model follow the ground surface more closely. Two iteration parameters, iteration angle and iteration distance, determine how close a point should be to a triangle plane so that the point could be accepted to the ground model. **Iteration angle** is the maximum angle between points, its projection on triangle plane and closest triangle vertex. **Iteration distance** parameter makes sure that the iteration does not make big jumps upwards when triangles are large. This helped to keep low buildings out of the ground model.



The vegetation and buildings were removed to obtain bare-earth. Even in areas covered by dense vegetation, ground points were correctly classified.

- Filtered the bare-earth data to remove small undulations.

Small random errors existed in the data due to electronic noise within the system. These errors manifest themselves as small undulations in the data. Using a software application based on a Gaussian operator and modified to for LiDAR data, Photo Science removed these small undulations. The filter controls accuracy by an elevation tolerance setting to meet a given accuracy threshold. The tolerance determines the maximum allowable elevation change of laser points. A data structure was developed suitable for LiDAR so that the searching routine is very fast [O(1)] computational complexity] making this algorithm quite efficient.

- Edge matched individual flight lines, generated statistics on the fit, and clipped the flight lines to butt match each other.

  The next step in the process was to clip individual flight lines such that adjacent flight lines butt match and a homogenous LiDAR coverage were provided across the entire mapping limit, without overlap. A software routine was utilized to follow the overlap region between two adjacent flight lines and place a "cut line" in the middle of the overlap region.

  If all flights were consistent within the mapping specifications, ground control data was imported and studied for fit. As a QC measure, statistical reports were then generated for comparison of LiDAR points, ground control, and TINs generated by LiDAR points. The absolute accuracy was determined by comparison with ground control. Statistical analysis was then performed on the fit between the LiDAR data and the ground control. Based on the statistical analysis, the LiDAR data was then adjusted in relation to the ground control.

- Translated the Bare-Earth Data Into the Appropriate Map Projection

  Once all of the data has been reduced and quality controlled, the bare-earth data was translated into the final map projection. Note that the airborne GPS aircraft trajectory was processed in the target datums in relation to the orthometric height. Photo Science used National Geodetic Survey's GEOID03 software to derive the orthometric height.

  The raw LiDAR point cloud data was derived in State Plane coordinates. All subsequent processing was carried out in this projection to avoid introducing errors associated with and moving across larger scale map projection zones. The data was translated into the target map projection through the coordinate conversion software. The entire transformation was generally setup and run in a batch mode.

  As a final quality control step, the orthometric heights were compared against ground survey results.

SECTION 5

LiDAR CALIBRATION AND ACCURACY OVERVIEW

SECTION 5: ALS50 SYSTEM CALIBRATION TECHNIQUES AND ACCURACY REPORTS

Introduction

This Leica ALS50 and ALS50-II LiDAR System Calibration Report are used to represent confirmation of the LiDAR system specifications, performance, and requirements. The system functionality, elevation, and horizontal accuracy performance shall be demonstrated for calibration purposes. The following data is *representative* of the calibration for the units used by Photo Science and its sub contractors in collecting the PaMAP LIDAR data in 2006, 2007 and 2008.

This report contains various test results and information pertaining to the system. It should be noted that all numbers shown in this report are in **meters** unless otherwise stated. All coordinates stated in the report are in the WGS84 coordinate system with ellipsoidal elevation.

System Model Number:	ALS50 and ALS50-II
Client Name:	PA MAP
Calibration Date	March, 2008

System Specifications and Requirements

The ALS50 LiDAR systems, built by Leica Geo-Systems have the following specifications:

Nominal	
Operating Altitude	400 – 3,000 meters
Elevation accuracy	15cm single shot (one standard deviation)
Range Resolution	1 cm
Scan angle	Variable from 0 to 75°
Swath width	Variable from 0 to 1.5 X altitude
Scan frequency	Variable based on scan angle
Horizontal Accuracy	Better than 1/2000 X altitude
Supported GPS receivers	Ashtech Z12, Trimble 7400, Novatel Millenium
Laser repetition rate	58 kHz
Beam divergence	0.3 mrads
Laser classification	Class IV laser product (FDA CFR 21)
Eye safe range	400m single shot depending on laser repetition rate

Power requirements	28 VDC @ 25A
Operating temperature	10-35°C
Humidity	0-95% non-condensing

The ALS50-II LiDAR system, built by Leica Geo-Systems has the following specifications:

Nominal	
Operating Altitude	Up to 6,000 meters
Elevation accuracy	8 – 24 cm single shot (one standard deviation)
Range Resolution	Better than 1 cm
Scan angle	Variable from 0 to 75°
Swath width	Variable from 0 to 1.5 X altitude
Scan frequency	Variable based on scan angle
Horizontal Accuracy	7 – 64 cm (one standard deviation)
Supported GPS receivers	Ashtech Z12, Trimble 7400, Novatel Millenium
Laser repetition rate	Up to 150 kHz
Beam divergence	0.3 mrads
Laser classification	Class IV laser product (FDA CFR 21)
Eye safe range	400m single shot depending on laser repetition rate
Power requirements	28 VDC @ 25A
Operating temperature	0-40°C
Humidity	0-95% non-condensing

On Site Antenna Offsets and Location

Aircraft GPS Antenna

Measurements from the Aircraft Antenna to the instrument are surveyed as well as predicted by the processing software. Photo Science utilized three different aircraft during the course of this acquisition. Additionally subcontractors used different aircraft as well. Specific information can be provided if needed. Additionally this information is available in the LiDAR LAS files (part of the data delivery).

Reference to IMU Lever arms

The following measurements were calculated in the lab at Leica and will remain constant.

User to IMU Lever Arm (POS/AV) for AIMU in ALS50 SH19	
X	**-0.269 m**
Y	**0.139 m**
Z	**-0.017 m**

User to IMU Lever Arm (POS/AV) for LN200 in ALS50-II SH59	
X	-0.273 m
Y	0.161 m
Z	-0.017 m

SN19 is equipped with AIMU and SN59 is equipped with LN200.

Base Station GPS and Antenna

Typically Photo Science utilizes Trimble 5700 GPS receivers for ground station base receivers. The other subcontractors utilize the same or similar equipment, capable of receiving GPS signals at 1 Hz or better
.

Monument Description:	
GPS Receiver Type: Trimble 5700 Antenna Type: Trimble	Epoch Interval: 0.5 sec Elevation Mask: 10 degrees Observation Type: Static

Flight Calibration Methodology

Data Collection

To accomplish the formal calibration, Photo Science has established a calibration range consisting of an airport runway and other features in central Kentucky. The calibration range has been ground surveyed to an accuracy of better than 1 cm. Four flight lines with two different altitude and opposing headings (see Figure 5-3) are required in order to capture pitch, roll, heading (see Figure 5-1) and torsion errors (see Figure 5-2). This calibration range is captured at least twice per year, or more frequently as deemed necessary. Additionally anytime the unit is removed from the Aircraft it is calibrated immediately upon installation in another or the same aircraft. Photo Science and subcontractors also set-up “mini” calibration sites at smaller airports or areas for each individual project or project area. These are flown before an area is captured, at least once during capture and immediately upon completing acquisition for an area. This is accomplished in case something changes in the set-up that may be caused by equipment being moved in the aircraft for maintenance, extreme turbulence, or environmental factors (extreme heat, cold or moisture). The information below is typical of a calibration site, and may or may not be one utilized by Photo Science or any of the subcontractors.

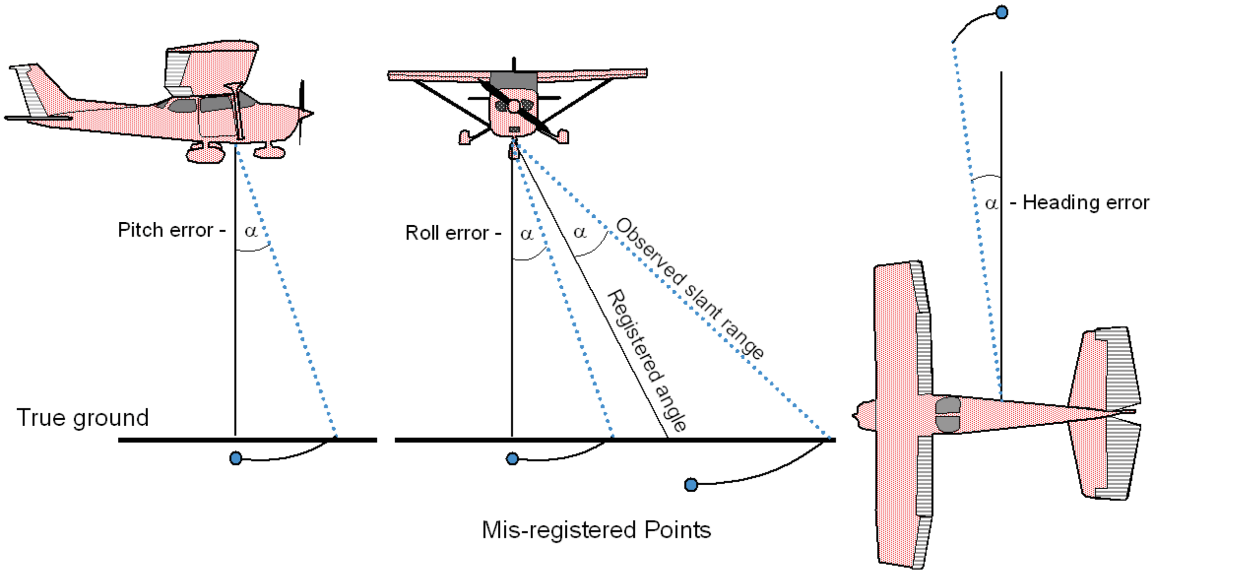


Figure 5-1: Misalignment Errors.

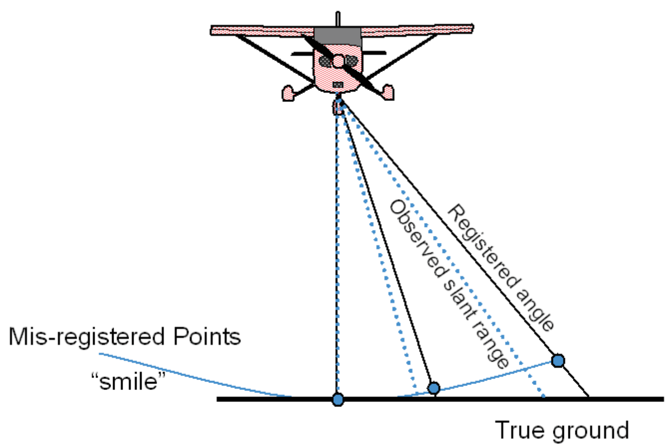


Figure 5-2: Torsion Error

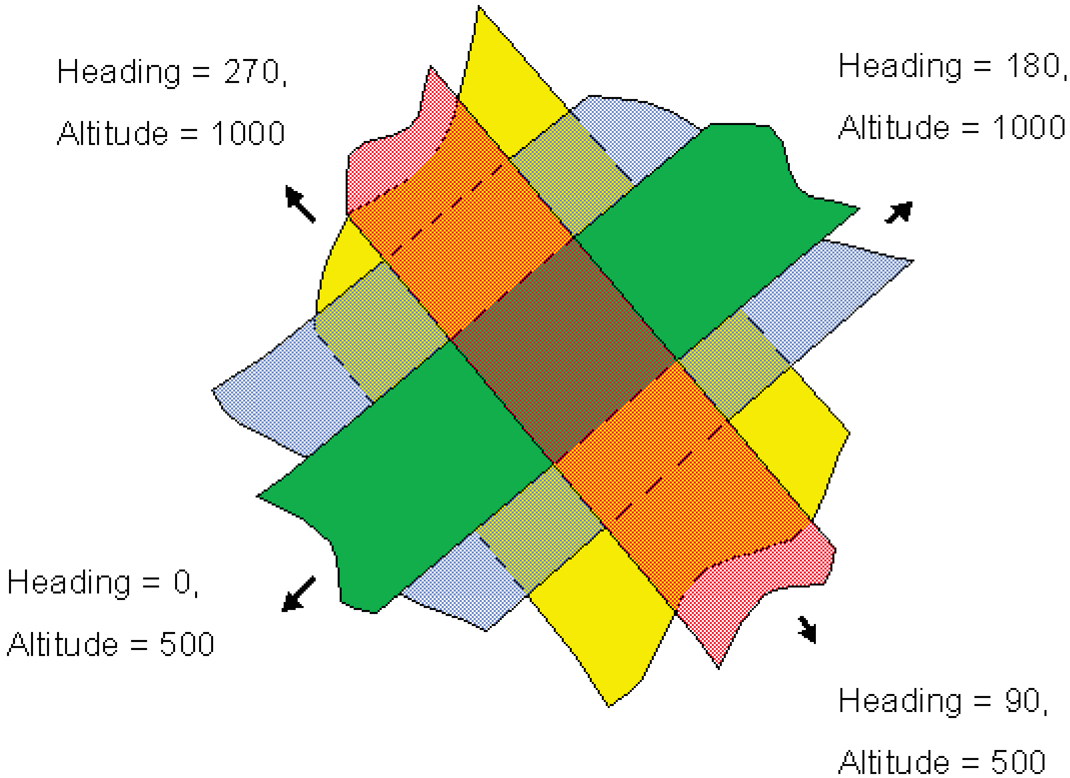


Figure 5-3: Optimal Flight Pattern for Calibration

Intensity Images

Four images from LiDAR intensity reflectance are generated in order to pick up tie points (see Figure 5-4). A least square adjustment (LSA) is performed using auto bore-sighting software provided by system manufacturer. Pitch, roll, heading, and torsion errors are calculated by LSA.

Figure 5-4: Ortho photo generated from LiDAR intensity reflectance.

Ground Control Points

Ground control points were collected along and across an airport runway. In this case a total of 116 runway points were surveyed. The LiDAR collects scan data over the control points and the data is then used to determine the absolute Z accuracy of the system. The distribution of the runway points can be found in Figure 5.5.

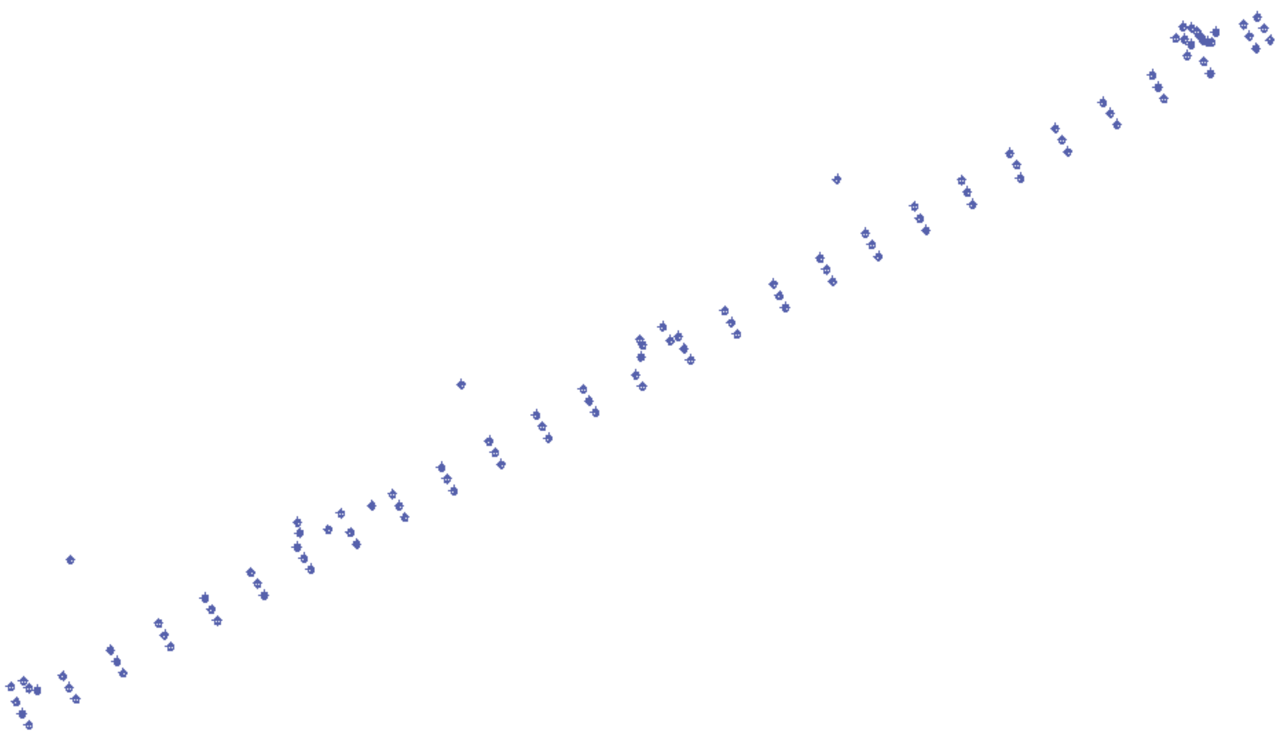


Figure 5-5: Ground control points on the runway

Flight over Ground Control Points

Flight lines, flown parallel and perpendicular to the runway control points were used to determine the elevation (Z) error of the LiDAR data as well as pitch, roll, heading, and torsion can be seen in Figure 5-6. Each day the runway was flown, multiple overlapping strips were performed to assure that most control points were covered and to increase the likelihood that a laser point would strike within 0.5 meters of a control point.

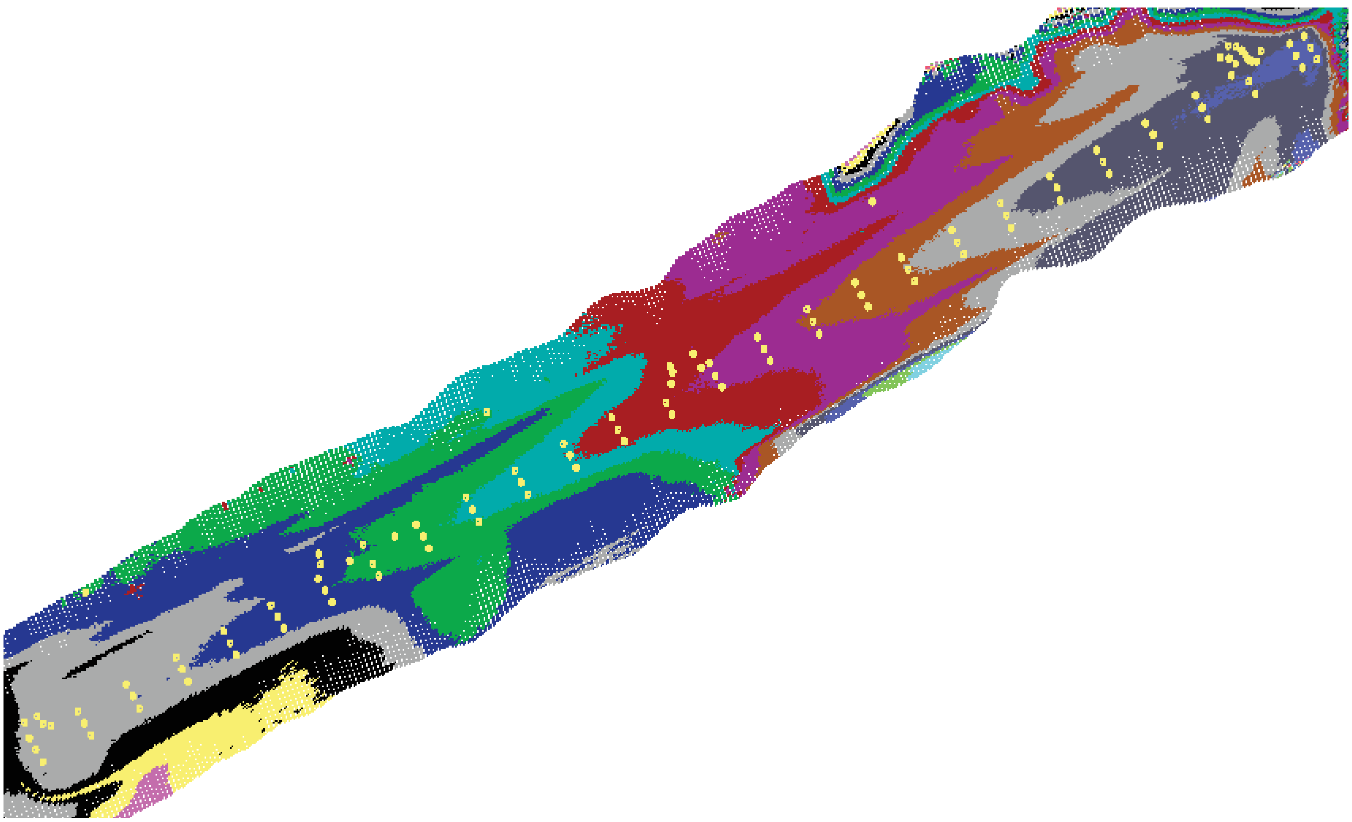


Figure 5-6: One flight line parallel to the runway ground control points. The flight line is color coded bv elevation.

All missions flown by Photo Science and its subcontractors were flown with current calibration data for the particular unit were applied for that flight. Additionally, mini calibration flights would have also been applied.

Accuracy Assessments

Accuracy assessments were made against all data for each of the years of collection. The accuracy is assessed by comparison of the LiDAR data against ground surveyed check points collected just for that reason. Photo Science sub consultant, Rettew Associates of Lancaster, PA, provided GPS check point surveying services for all three project years in up to five (5) different land cover categories establishing 120 points in the 2006 project area including 20 points in Luzerne County, 100 points each in both the 2007 and 2008 project areas. Rettew's Report of Survey for each of the three project years has been separately provided to BAE Systems. Additionally, Photo Science utilized supplemental existing ground control data from concurrent and/or prior PAMAP imagery projects as well as any reliable available control points established by NGS, PennDOT, etc. Lastly, PAMAP QA Consultant, Dewberry, conducted comprehensive qualitative and quantitative reviews and accuracy assessments of the PAMAP LiDAR datasets. The results of their assessments can be found on the PAMAP Web Site at http://www.dcnr.state.pa.us/topogeo/pamap/documents.aspx.

Generally ground points are acquired in relatively flat open areas at least five meters from potential breaklines so that a fair assessment may be determined against the LiDAR data set. Horizontal placement is hard to determine against LiDAR data and the emphasis is against the vertical component.

The information below are Photo Science readings made against the LiDAR data for specific points delivered to the PAMAP program over the three year period and in cover different geographic areas, by year. Woolpert and BAE Systems would have made similar comparisons using the Rettew check points and other control for the areas that they were processing.

All readings/values are expressed in **US SURVEY Feet**.

2006- 21 County Area- Collection Block 2 (Northwest)

2006-RETTEW GPS CHECK POINT COMPARISON					
Statistical Analysis					
Average Dz	0.284				
Minimum Dz	-1.064				
Maximum Dz	1.276				
RMSE	0.472				
Standard Deviation	0.379				
Point	**Easting**	**Northing**	**Known Z**	**LIDAR Z**	**Dz**
BE1	2520771.030	423758.910	924.744	925.030	0.286
BE10	1313299.514	456318.715	1248.776	1248.9	0.124

BE11	1214931.404	488898.423	800.58	801.17	0.590
BE12	1361701.834	394822.873	1494.135	1494.3	0.165
BE13	1290555.683	391991.013	1197.556	1198.02	0.464
BE14	1346715.770	619540.151	1219.66	1219.88	0.221
BE15	1842013.351	502024.933	1083.129	1083.14	0.011
BE16	1719646.41	368181.745	1701.177	1701.16	-0.017
BE17	1646434.766	359149.59	1758.928	1759.7	0.772
BE18	1820195.486	473362.243	947.933	948.65	0.717
BE19	1778981.569	380228.46	1064.761	1064.61	-0.151
BE2	2460210.500	411706.600	1119.035	1119.770	0.735
BE20	1778232.402	437522.013	1737.812	1737.62	-0.192
BE21	1508282.915	542477.121	1021.38	1021.13	-0.252
BE22	1563325.828	536725.283	1341.84	1341.93	0.090
BE23	1654130.463	340121.701	1710.036	1710	-0.036
BE24	1668503.952	333873.165	1972.768	1972.81	0.042
BE3	2448877.060	384021.620	538.718	539.040	0.322
BE4	2461257.500	316656.270	1181.145	1181.960	0.815
BE5	1956285.495	588627.811	735.816	736.05	0.234
BE6	2008499.531	629792.822	605.978	606.08	0.102
BE7	1962475.82	613928.348	968.433	968.86	0.427
BE8	1312896.604	500511.278	1032.416	1032.6	0.184
BE9	1342696.786	491660.417	1297.725	1297.71	-0.015
BR1	2520843.47	423895.12	918.816	918.86	0.044
BR10	1315038.965	452264.168	1185.632	1185.85	0.218
BR11	1214882.164	489008.483	802.057	802.73	0.673
BR12	1361624.775	394694.025	1475.595	1475.7	0.105
BR13	1290824.053	391756.915	1201.148	1201.83	0.682
BR14	1346738.962	619274.339	1211.89	1212.53	0.645
BR15	1842154.896	501378.094	1107.63	1108.14	0.51
BR16	1720551.957	368691.536	1664.984	1665.1	0.116
BR17	1645699.578	359347.218	1748.592	1749.27	0.678
BR17	1645699.578	359347.218	1748.592	1749.27	0.678
BR18	1820366.832	473452.172	945.089	945.96	0.871
BR19	1778774.773	380382.477	1078.816	1078.95	0.134
BR2	2456579.87	409646.42	1088.95	1089.8	0.85
BR20	1778390.772	437692.515	1728.987	1729.11	0.123
BR21	1508350.910	542476.172	1020.90	1021.77	0.868
BR22	1563517.946	536787.787	1360.07	1360.17	0.097
BR23	1653952.891	339923.85	1687.414	1687.96	0.546
BR24	1668572.962	334071.263	1968.71	1968.79	0.08
BR3	2448405.81	384679.43	534.986	535.59	0.604

BR4	2461221.53	316770.21	1180.976	1181.99	1.014
BR5	1956605.516	587684.284	700.562	701.26	0.698
BR6	2008350.234	630504.698	612.467	outside	*
BR7	1964754.101	616469.279	951.138	951.6	0.462
BR8	1313012.385	500377.432	1010.066	1010.34	0.274
BR9	1342575.214	491820.625	1303.048	1303.28	0.232
FF1	2520496.92	423889.3	914.591	914.86	0.269
FF10	1313138.591	456460.501	1219.481	1220.06	0.579
FF11	1214832.719	489044.73	809.082	810.2	1.118
FF12	1361433.674	394804.739	1479.401	1479.09	-0.311
FF13	1290574.237	391853.448	1202.461	1202.74	0.279
FF14	1346537.516	619395.740	1202.89	1202.93	0.045
FF15	1842215.804	501387.256	1131.456	1132.14	0.684
FF16	1720496.685	368866.343	1690.735	1690.92	0.185
FF17	1646275.511	358538.838	1774.199	1773.93	-0.269
FF18	1819954.487	473106.813	948.356	949.16	0.804
FF19	1779074.502	380422.079	1098.741	1098.99	0.249
FF2	2460911.15	411401.25	1177.242	1177.71	0.468
FF20	1778475.489	437526.127	1755.589	1755.82	0.231
FF21	1507745.348	542793.504	1043.74	1043.44	-0.3
FF22	1563598.843	536919.901	1358.27	1358.20	-0.07
FF23	1654078.049	340725.761	1797.851	1798.26	0.409
FF24	1668813.018	334227.785	1961.078	1961.47	0.392
FF3	2448618.83	384780.25	539.12	539.62	0.5
FF4	2461479.01	316883.46	1206.875	1207.73	0.855
FF5	1955839.049	588939.238	809.844	811.12	1.276
FF6	2007941.505	628512.988	617.471	618.06	0.589
FF7	1962045.917	613742.572	963.287	963.82	0.533
FF8	1313300.593	500457.178	1009.488	1010.08	0.592
FF9	1342733.842	491929.913	1301.691	1302.22	0.529
HG1	2522670.82	425147.43	966.5	967.02	0.52
HG10	1313335.117	456546.656	1247.908	1248.1	0.192
HG11	1214910.915	488808.326	787.292	787.38	0.088
HG12	1361578.839	395021.574	1460.295	1460.32	0.025
HG13	1290744.51	391841.983	1202.696	1203.01	0.314
HG14	1346809.183	619282.065	1216.94	1217.44	0.505
HG15	1842021.595	501657.915	1090.73	1090.65	-0.08
HG16	1720269.18	368778.411	1692.831	1692.97	0.139
HG17	1645920.851	359301.769	1753.874	1754.7	0.826
HG18	1819804.515	473191.067	950.333	950.84	0.507
HG19	1778985.104	380396.007	1100.847	1101.26	0.413

HG2	2460140.89	411666.3	1122.534	1123.14	0.606
HG20	1778306.27	437549.753	1738.125	1738.12	-0.005
HG21	1507720.935	542640.533	1015.14	1015.20	0.063
HG22	1563198.309	536717.201	1342.38	1342.69	0.309
HG23	1654057.681	340414.668	1746.614	1746.78	0.166
HG24	1668284.065	333946.919	1975.51	1975.92	0.41
HG3	2448653.29	384422.2	537.089	537.57	0.481
HG4	2461150.27	316778.81	1174.75	1175.61	0.86
HG5	1955999.055	588862.043	786.218	786.98	0.762
HG6	2008387.009	629122.798	592.629	592.26	-0.369
HG7	1961936.447	614243.555	953.212	953.48	0.268
HG8	1313565.306	500640.76	1031.222	1031.39	0.168
HG9	1342728.027	491572.321	1292.953	1293.11	0.157
UA1	2520136.26	423227.2	914.648	914.53	-0.118
UA10	1314975.212	452457.661	1200.158	1200.54	0.382
UA11	1215086.251	488877.359	804.445	805.4	0.955
UA12	1359917.152	393966.822	1433.65	1433.26	-0.390
UA13	1290167.916	393031.591	1159.548	1159.62	0.072
UA14	1343190.842	623417.508	1256.74	1256.51	-0.226
UA15	1841219.351	492128.362	1036.43	1035.78	-0.650
UA16	1720084.429	368783.373	1707.96	1707.99	0.030
UA17	1646204.88	358954.552	1749.356	1749.17	-0.186
UA18	1819469.81	473398.618	954.506	955	0.494
UA19	1778839.44	377316.091	1008.414	1008.58	0.166
UA2	2459868.19	411758.7	1109.727	1109.87	0.143
UA20	1777981.632	437598.706	1716.196	1716.13	-0.066
UA21	1508091.714	542691.717	1029.23	1028.17	-1.064
UA22	1563199.408	536998.510	1331.71	1331.46	-0.249
UA23	1659241.465	343677.349	2001.006	2001.38	0.374
UA24	1668958.976	333712.211	1972.364	1972.4	0.036
UA3	2449141.64	383353.51	563.591	563.29	-0.301
UA4	2461771.34	316635.52	1224.295	1224.56	0.265
UA5	1954899.942	586718.974	728.887	728.68	-0.207
UA6	2009848.184	630403.767	623.625	623.72	0.095
UA7	1961878.194	614356.787	960.404	960.51	0.106
UA8	1312893.884	501492.658	1033.676	1034.18	0.504
UA9	1343074.36	491809.083	1295.003	1295.09	0.087

2006-OTHER CONTROL POINT COMPARISON					
Statistical Analysis					
Average Dz	-0.207				
Minimum Dz	-0.657				
Maximum Dz	0.39				
RMSE	0.321				
Standard Deviation	0.252				
Point	**Easting**	**Northing**	**Known Z**	**LIDAR Z**	**Dz**
11	1251621.47	487308.74	1016.76	1016.28	-0.48
12	1300221.31	492434.91	1332.67	1332.08	-0.59
306	1633322.87	289190.94	1257.04	1256.77	-0.27
356	1197355.38	403070.48	1044.85	1044.43	-0.42
357	1196224.70	457162.74	923.40	923.31	-0.09
358	1407749.97	472591.33	1495.87	1495.21	-0.66
359	1409385.01	420188.67	1528.32	1527.97	-0.35
368	1641486.93	411245.80	1647.74	1647.77	0.03
369	1632881.44	354866.43	1545.20	1544.82	-0.38
376	1269184.36	433752.72	1229.79	1229.82	0.04
377	1263625.20	365802.91	1072.35	1072.16	-0.19
378	1347870.88	379832.01	1439.63	1439.42	-0.21
379	1339078.20	442171.98	1449.07	1448.87	-0.20
380	1500135.74	465252.66	1549.31	1549.24	-0.06
381	1487607.20	380583.68	1457.52	1457.14	-0.38
382	1576565.02	403607.39	1734.93	1734.80	-0.13
383	1574573.14	465218.72	1645.20	1645.23	0.03
384	1559846.98	336794.26	1245.76	1245.72	-0.04
N63	1334352.86	364036.95	1282.01	removed	*
TT64K	1644238.74	517429.42	1881.97	1882.36	0.39

2006-OTHER CONTROL POINT COMPARISON

Statistical Analysis	
Average Dz	-0.102
Minimum Dz	-0.471
Maximum Dz	0.44
RMSE	0.307
Standard Deviation	0.3

Point	Easting	Northing	Known Z	LIDAR Z	Dz
N63	1334309.34	667418.58	1282.01	removed	*
377	1263576.20	669146.40	1072.35	1071.88	-0.47
406	1510311.77	540832.45	1076.50	1076.04	-0.46
309	1308093.96	596589.28	1310.13	1309.74	-0.39
361	1415282.21	528986.54	1341.98	1341.60	-0.38
370	1625759.22	528769.59	1722.42	1722.11	-0.31
405	1566093.17	493290.68	1028.73	1028.49	-0.24
302	1187399.42	586463.38	1101.59	1101.37	-0.22
360	1411686.12	644308.34	1453.53	1453.35	-0.18
307	1493287.62	600135.32	1429.98	1429.86	-0.12
371	1642693.68	468349.58	1552.41	1552.40	-0.01
403	1583522.23	410542.54	1798.21	1798.23	0.02
355	1199736.30	632037.13	827.68	827.79	0.11
308	1410572.20	588316.41	1397.91	1398.20	0.29
301	1190801.34	596068.43	1100.17	1100.56	0.39
E402	1557804.36	538493.79	1219.07	1219.51	0.44

2007- 21 County Area- South Zone Collection Blocks

2007-RETTEW GPS CHECK POINT COMPARISON

Statistical Analysis	
Average Dz	0.128
Minimum Dz	-0.384
Maximum Dz	0.873
RMSE	0.289
Standard Deviation	0.263

Point	Easting	Northing	Known Z	LIDAR Z	Dz
BE-13	1896941.465	417145.201	609.456	609.87	0.414
BE-14	1663418.979	323761.348	2005.010	2005.08	0.070
BE-15	1591372.003	156232.769	2040.948	2040.74	-0.208
BE-16	1735827.262	168240.563	1104.858	1104.83	-0.028
BE-17	1844192.321	154495.452	520.028	520.06	0.032
BE-18	1978727.438	165499.253	642.032	642.20	0.168
BE-19	2120563.940	184574.054	535.074	534.91	-0.164
BE-20	2094842.077	281112.046	607.999	607.90	-0.099
BE-21	2138486.905	412871.381	405.625	405.47	-0.155
BR-13	1896825.322	416958.135	606.070	606.80	0.729
BR-14	1663268.889	324399.398	1988.325	1988.16	-0.165
BR-15	1590815.163	156351.231	2001.051	2001.23	0.178
BR-16	1730989.205	166198.409	1219.006	1219.41	0.404
BR-17	1844773.190	154262.271	539.632	539.95	0.318
BR-18	1978617.782	165436.866	652.292	652.36	0.068
BR-19	2120464.633	184599.619	531.612	531.82	0.208
BR-20	2095213.404	281195.812	599.823	600.14	0.317
BR-21	2138642.576	412827.484	401.955	402.22	0.265
FF-13	1897070.082	417367.683	610.694	611.19	0.496
FF-14	1663415.437	324191.340	1999.842	2000.11	0.268
FF-15	1590987.753	156425.453	2006.908	2006.97	0.062
FF-16	1735736.210	168137.908	1104.310	1104.67	0.360
FF-17	1844384.625	154326.817	532.962	532.86	-0.102
FF-18	1978712.195	165552.858	640.135	640.16	0.025
FF-19	2120527.505	184527.432	531.434	531.83	0.400
FF-20	2095045.171	281159.663	601.030	601.41	0.380
FF-21	2138832.963	413046.992	400.967	401.36	0.393
HG-13	1896887.594	417056.549	607.548	608.05	0.502
HG-14	1663321.516	324301.280	1990.751	1990.78	0.029

HG-15	1590892.977	156472.413	2000.973	2000.90	-0.073
HG-16	1735838.478	168488.682	1109.100	1109.12	0.020
HG-17	1844386.152	154429.391	525.371	525.44	0.069
HG-18	1978802.110	165709.064	638.690	638.76	0.070
HG-19	2120606.210	184532.550	535.978	536.18	0.202
HG-20	2095139.429	281092.446	603.187	604.06	0.873
HG-21	2138148.063	413236.325	418.941	419.02	0.079
UA-13	1896517.424	417368.405	613.883	613.92	0.037
UA-14	1663431.179	323628.819	2009.610	2009.30	-0.310
UA-15	1591486.433	156235.564	2047.714	2047.33	-0.384
UA-16	1735772.835	168241.752	1107.386	1107.44	0.054
UA-17	1844495.783	154379.882	526.270	526.08	-0.190
UA-18	1976721.578	165354.594	611.331	611.37	0.039
UA-19	2120720.136	184623.923	542.519	542.69	0.171
UA-20	2091911.927	280387.155	611.939	612.09	0.151
UA-21	2140840.125	416814.873	391.815	391.59	-0.225

2007-OTHER CONTROL POINT COMPARISON

Statistical Analysis	
Average Dz	-0.007
Minimum Dz	-0.73
Maximum Dz	0.79
RMSE	0.292
Standard Deviation	0.294

Point	Easting	Northing	Known Z	LIDAR Z	Dz
737	2168717.999	348136.685	447.667	447.960	-0.51
814	2026310.042	132857.926	716.982	717.320	-0.46
706	2187495.148	440303.509	430.990	431.340	-0.45
716	2160048.443	142613.193	628.418	628.830	-0.39
748	2084804.079	387190.432	733.774	734.280	-0.29
763	2071720.751	283927.035	720.286	720.800	-0.29
754	1783814.094	247262.397	1107.873	1108.450	-0.22
762	1978650.010	263949.534	742.956	743.540	-0.22
713	2184697.110	221446.229	421.872	422.470	-0.20
767	2022885.225	186642.158	854.623	855.240	-0.18
723	1785241.241	133493.666	1634.456	1635.080	-0.18
709	2200449.574	343877.784	388.629	389.270	-0.16
719	1974366.381	141574.010	673.835	674.510	-0.13
755	2124521.166	290918.048	566.815	567.490	-0.13

708	2185202.398	378053.217	444.591	445.270	-0.12
745	1971422.956	424739.545	507.050	507.730	-0.12
750	2103741.573	448162.329	645.178	645.880	-0.098
764	1992839.745	220749.568	603.833	604.540	-0.093
714	2193729.542	190079.778	1162.099	1162.820	-0.079
735	2101361.188	347636.382	902.249	903.000	-0.049
741	1939842.323	170715.491	520.254	521.010	-0.044
712	2177022.172	244611.354	439.237	440.010	-0.027
765	2050006.477	233355.655	1900.467	1901.240	-0.027
768	2127940.573	202865.525	559.735	560.510	-0.025
724	1730858.079	137274.964	1004.532	1005.320	-0.012
720	1936047.040	139241.487	525.743	526.580	0.037
734	2054799.201	337072.487	650.565	651.420	0.055
802	2137355.892	427486.215	564.935	565.790	0.055
74	2154096.369	483958.948	681.987	682.870	0.083
766	2121914.437	247309.676	797.115	798.030	0.115
707	2196298.250	414667.042	410.077	411.000	0.123
773	1765389.303	177277.422	1043.139	1044.070	0.131
753	2008509.761	298877.216	740.955	741.910	0.155
742	2075563.537	165942.670	606.632	607.600	0.168
816	2132318.707	163002.335	509.276	510.270	0.194
717	2094707.752	142735.303	516.875	517.910	0.235
815	2098634.776	132496.138	419.331	420.430	0.299
769	1823431.627	292107.397	871.530	872.660	0.33
73	2111523.943	487095.472	732.114	733.270	0.356
751	2008668.957	377900.930	631.169	632.350	0.381
749	2136790.006	385775.199	713.570	714.760	0.39
746	2023782.922	453850.366	550.660	551.910	0.45
747	2066963.995	417916.637	1128.713	1130.120	0.607
772	1743784.381	229423.679	1258.077	removed	*
203	1696931.443	184000.707	1000.776	1000.150	-0.726
314	1849681.444	475991.242	1024.597	1024.110	-0.587
209	1604047.522	207121.458	2406.082	2405.630	-0.552
774	1820891.643	185282.426	1177.273	1176.850	-0.523
200	1734444.023	339882.791	1449.166	1448.760	-0.506
203A	1696802.263	184048.037	1002.266	1001.870	-0.496
207	1555375.474	142246.856	2670.123	2669.770	-0.453
727	1772851.010	352963.195	1150.975	1150.700	-0.375
730	1846647.175	438729.989	1057.591	1057.370	-0.321
771	1849365.126	250789.454	1866.645	1866.440	-0.305
813	1883079.421	132596.437	445.378	445.270	-0.208

752	1836056.905	494231.808	1015.340	1015.300	-0.14
201	1711777.054	312048.057	1869.925	1869.890	-0.135
201	1711777.054	312048.057	1869.925	1869.890	-0.135
770	1881875.833	289017.549	851.157	851.160	-0.097
197	1608399.557	350031.240	2238.103	2238.110	-0.093
733	1977705.331	346709.694	734.956	734.970	-0.086
756	1674756.681	284196.157	2167.945	2167.960	-0.085
195	1577515.224	304467.756	2741.285	2741.320	-0.065
202A	1692906.390	260529.096	1827.142	1827.190	-0.052
210	1617276.736	283459.560	1995.390	1995.440	-0.05
725	1681508.143	222099.528	2221.138	2221.200	-0.038
194	1537554.498	257108.884	2548.239	2548.320	-0.019
332	1761838.324	312308.079	1328.436	1328.550	0.014
211	1653123.590	235766.596	2371.744	2371.860	0.016
329	1851821.404	347264.159	1225.602	1225.730	0.028
205	1665542.129	144300.304	1777.374	1777.520	0.046
205	1665542.129	144300.304	1777.374	1777.520	0.046
805	1936262.096	302191.779	1051.667	1051.820	0.053
743	1907148.142	433701.353	634.079	634.240	0.061
317	2006215.011	486979.057	770.941	771.120	0.079
728	1833556.018	378497.479	1164.391	1164.590	0.099
739	1936803.006	273344.941	974.034	974.240	0.106
198	1645975.604	337424.724	1751.028	1751.270	0.142
323	1947684.303	481364.292	763.283	763.540	0.157
744	1917208.874	389022.405	782.873	783.150	0.177
731	1891239.183	349161.243	1269.632	1269.910	0.178
202	1692898.745	260536.820	1827.258	1827.570	0.212
208A	1547884.557	215017.574	2278.354	2278.700	0.246
204	1688362.141	164455.329	1037.058	1037.410	0.252
722	1846822.381	136826.645	563.476	563.850	0.274
810	1941011.280	243428.504	1147.469	1147.850	0.281
775	1890257.760	194146.658	774.978	775.390	0.312
206	1616374.431	151820.627	2463.731	2464.180	0.349
196	1592458.149	345114.150	2364.487	2365.020	0.433
72A	2066614.094	501838.557	704.641	705.350	0.609
702	1898875.142	499869.671	1081.503	1082.360	0.757
732	1933774.933	348029.830	662.985	663.870	0.785

2008- 25 County Area- South Zone Collection Blocks

2007-RETTEW GPS CHECK POINT COMPARISON

Statistical Analysis	
Average Dz	0.169
Minimum Dz	-0.819
Maximum Dz	0.84
RMSE	0.393
Standard Deviation	0.358

Point	Easting	Northing	Known Z	LIDAR Z	Dz
BE1	2339992.48	182761.96	700.01	700.62	0.61
BR1	2339980.61	182687.90	698.92	699.76	0.84
FF1	2340326.37	183297.89	700.60	700.97	0.37
HG1	2340010.05	183262.44	704.46	704.78	0.33
UA1	2340308.31	182470.29	700.91	701.51	0.60
BE2	2439580.61	227240.14	668.71	668.44	-0.27
BR2	2439483.36	227244.07	666.99	outside	*
FF2	2439477.44	227367.96	658.36	658.98	0.62
HG2	2439617.61	227170.17	666.27	665.80	-0.47
UA2	2435768.34	224671.99	677.52	677.96	0.44
BE3	2239531.08	367237.71	472.86	472.38	-0.48
BR3	2239417.56	366961.23	454.68	454.72	0.04
FF3	2239690.31	367280.17	468.98	468.83	-0.15
HG3	2239625.39	367275.23	471.38	470.83	-0.55
UA3	2239511.11	367341.11	471.12	470.30	-0.82
BE4	2361274.56	414459.74	496.08	496.49	0.41
BR4	2360486.53	414177.62	477.48	478.14	0.66
FF4	2360406.26	414158.47	476.92	477.49	0.58
HG4	2360656.20	414096.85	483.70	484.29	0.59
UA4	2360662.93	414246.01	485.16	485.40	0.25
BE5	2494974.88	410828.82	402.56	402.78	0.22
BR5	2495193.10	410441.81	411.79	412.51	0.72
FF5	2494927.53	410569.09	407.13	407.65	0.52
HG5	2494638.63	410234.17	423.97	424.12	0.15
UA5	2495111.57	411207.45	393.06	393.26	0.20
BE7	2623752.41	447241.30	395.68	395.69	0.01
BR7	2623712.42	447169.31	396.19	396.44	0.25
FF7	2623754.72	446864.66	397.17	397.27	0.10
HG7	2623748.54	447338.28	394.90	394.82	-0.08

UA7	2623049.15	447018.77	401.63	401.52	-0.11
BE8	2766842.88	349419.54	221.08	221.31	0.23
BR8	2766892.29	349552.28	217.35	removed	*
FF8	2766786.76	349690.87	223.55	223.87	0.32
HG8	2766866.47	349638.48	221.22	221.08	-0.14
UA8	2767658.63	350243.66	232.51	232.85	0.34
BE9	2606909.07	205269.32	305.39	305.28	-0.11
BR9	2607065.06	205829.43	312.74	313.04	0.30
FF9	2606849.80	205846.24	314.62	314.84	0.22
HG9	2606914.14	205451.80	311.38	311.40	0.02
UA9	2606798.80	205224.05	310.02	309.90	-0.12
BE12	2610507.89	258380.22	463.72	463.66	-0.06
BR12	2610712.94	258491.26	461.01	outside	*
FF12	2610615.61	258075.68	449.44	449.18	-0.26
HG12	2610561.49	258401.90	464.03	463.98	-0.05
UA12	2610315.99	258507.33	456.50	456.51	0.01
BE20	2243195.98	281033.55	299.89	300.22	0.33
BR20	2243021.13	280671.33	306.62	307.45	0.83
FF20	2242945.47	280662.73	310.67	311.09	0.42
HG20	2243223.37	280701.26	298.37	298.80	0.43
UA20	2243655.06	280823.00	291.34	291.28	-0.06
M6	2295798.86	278343.24	462.41	462.31	-0.10
M368	2390450.86	198664.94	668.31	668.03	-0.28
BRANDPORT	2576573.66	246768.61	462.90	462.96	0.06
BM	2569762.40	237274.53	475.60	475.76	0.16
11B1	2790605.55	353802.53	131.49	outside	*
JORDAN	2597529.53	479595.78	334.06	334.74	0.68
KRUMS	2510768.25	459303.19	772.24	772.50	0.26
STRAUSS	2401859.99	428395.84	642.24	642.44	0.20
WOLFE	2282794.16	397029.82	512.29	512.35	0.06