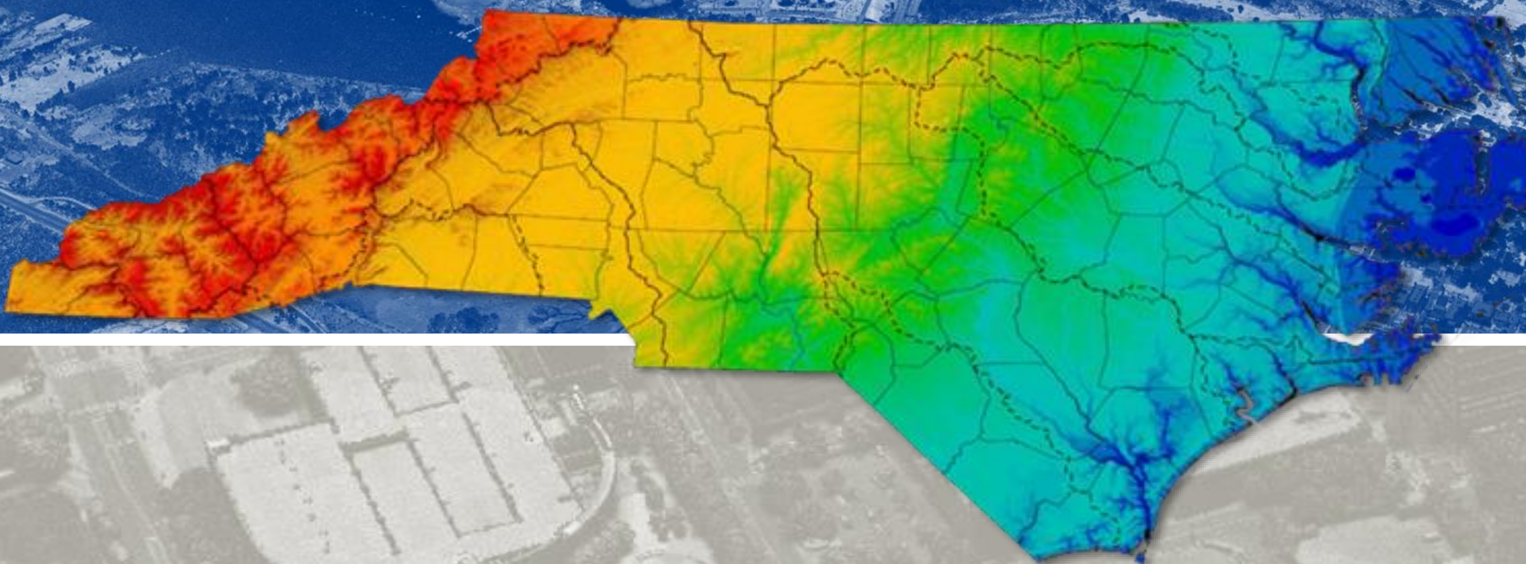

North Carolina Floodplain Mapping Program

286-000030 ESP

Post Acquisition Report

Delivery Order 22
Phase 4 LiDAR

September 19, 2017

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FIGURES

TABLES

1.0 – Overview

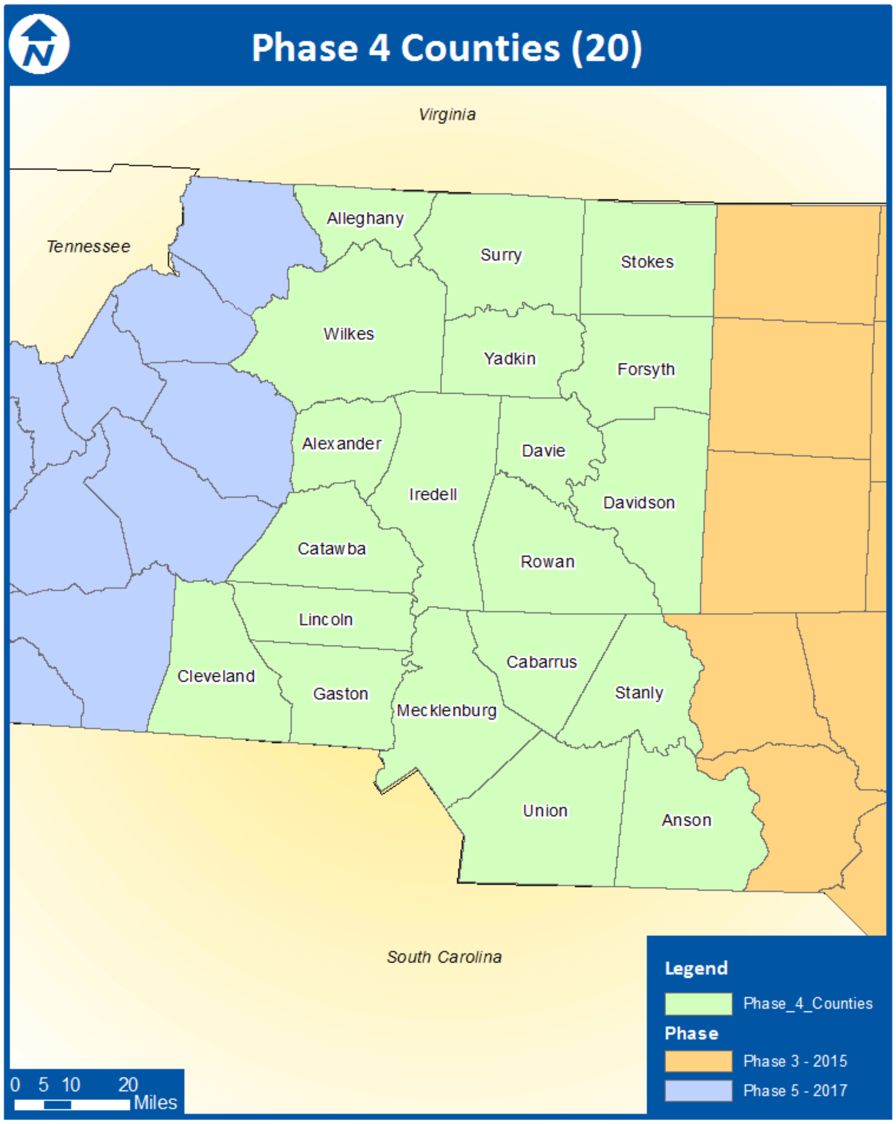
This Post-Acquisition Report provides a comprehensive accounting of the Geiger-Mode Aerial LiDAR collection of Phase 4 of the North Carolina Floodplain Mapping Program, 286-000030 ESP, Delivery Order 22. Due to a combination of external and internal factors, 49.3% of the project area was collected prior to leaf off conditions during January through April of 2016 and the remainder of the project was collected between December of 2016 and February of 2017.

The purpose of this aerial acquisition was to update existing LiDAR data from the previous program, originally collected between 2000 and 2006, with more accurate and clearly defined LiDAR data utilizing the latest in sensor technology. To that end, the State of North Carolina, Department of Public Safety, Division of Emergency Management, Risk Management (NCEM) issued Task Order 22 to ESP Associates, P.A. (ESP) to perform LiDAR data collection and processing and the generation of Hydro DEM raster products for the Phase 4 area covering portions of the Piedmont and Mountain regions of North Carolina. This Post-Acquisition Report details the LiDAR data acquisition process, area coverage and internal verification steps that were conducted in support of the program goals. The task order area encompassed ~9,338 square miles.

LiDAR data for the project and the validation site was collected by a single aerial vendor on ESP team between February 27, 2016 and April 17, 2016 and between December 9, 2016 and February 21 of 2017 using Geiger-mode Avalanche Photodiode (GmAPD) sensors. The aerial vendor on the ESP team was Harris Corporation (Harris). Throughout the project, the validation was flown additional times to verify sensor calibration and reliability when upgrades or repairs were made.

The project design was developed to ensure that the acquired LiDAR data met or exceeded the requirements for the current USGS Quality Level 1 (QL1) and State LiDAR Specifications with an aggregate nominal pulse density (ANPD) of >30 points per square meter (PPSM) for the collected density with a deliverable of 8 PPSM at an aggregate nominal post spacing (ANPS) of <0.35 meters. The project design supported an RMSE of 9.25 cm or better for NVA (USGS specifications modified to State-required 9.25cm from USGS-required 10 cm) Figure 1 below shows the North Carolina Counties for Phase 4 as approved by the NCEM for this Delivery Order.

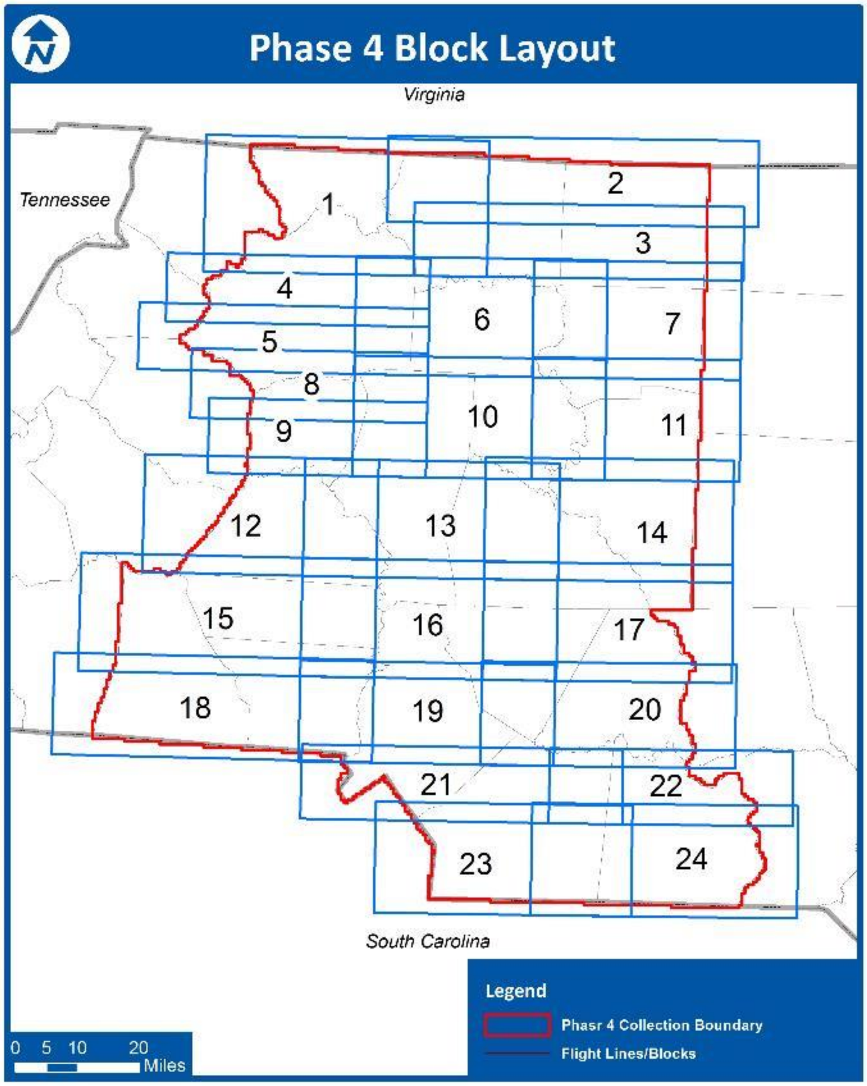
Figure 1: LiDAR collection counties and project boundary.



1.1– LiDAR Block Layout

The data collection plan was broken into a total of 24 sub-blocks shown in Figure 2. The sub-block plan included limiting flight line acquisition to < 20 minutes, or approximately 92 miles (based on the capabilities of the sensor and aircraft). This reduced the potential for inertial drift by improving inertial precision. In addition, each block contained sufficient overlap with adjoining blocks to be used for the bundle adjustment calibration procedure.

Figure 2: LiDAR block layout and assignments.



1.2 – Communications

Throughout the acquisition phase of the project, team member Harris conducted Flight Operations Management, which included coordination of daily flights, issue mitigation, coordination with FAA, and daily progress reporting to ESP. On a daily basis flight crews were required to report progress, lines tagged for reflight, and any issues encountered.

1.3 – Project Initiation

ESP hosted an internal Project Acquisition Kick-Off Meeting with Harris to establish final mobilization plans based on forecasted weather conditions and initial sub-task milestones. Plan development included the phases of mobilization, validation range acquisition, validation range data submittal, validation range data approval, and the start of project data acquisition.

2.0 – As-Flown Data

This section of the Post-Acquisition report covers “as-flown” information and includes sensor and flight parameters, aircraft used, flight trajectories, collection environment, base station layout, airport operations, airspace restrictions, validation, calibration, and re-flight procedures.

2.1 – Sensor and Flight Parameters (Planned vs. As-Flown)

The ESP team’s LiDAR sensors used on this project are presented in Table 1, below. Sensor # 003 was the original sensor on station until a hardware issue required the mobilization of Sensor # 002 to the project area. Both sensors were subsequently used to ensure completion of the project within flight seasons.

Table 1: LiDAR sensor type and serial numbers.

LiDAR Sensor	Serial Number
IntelliEarth GmAPD LiDAR	003
IntelliEarth GmAPD LiDAR	002

Acquisition specifications for this project are provided in Table 2, below.

Table 2: Acquisition specifications met.

Parameter	Specification
Boundary Buffer	≥ 100 meters beyond tile boundaries
Nominal Post Spacing (ANPS)	≤ 0.35 meters
Signal Returns	N/A (GmAPD systems are not multiple return systems)
Intensity	Each return pulse
Overlap	≥ 55%
Maximum Scan Angle	≤40 Degrees
Maximum Line Length	≤ 150km (92 miles)
Maximum Line Time	≤ 20 minutes
Clustering	Regular grid of with a cell size of 2*NPS
	≥ 90% of cells will contain at least one LiDAR point
	Tested against 1st return only
***Vertical Accuracy**	RMSEz = 9.25cm (NVA)
	FVA = 18.13 cm at 95% Confidence Level
	CVA = 26.9cm at 95th percentile
	VVA = 26.9cm at 95th percentile

***CVA and VVA are not calculated until LiDAR is classified**

2.2 – Utilized Aircraft

Table 3 summarizes the Team’s aircraft used for the project. The aircraft used was in compliance with FAA guidelines and regulations for operation, maintenance, and repair.

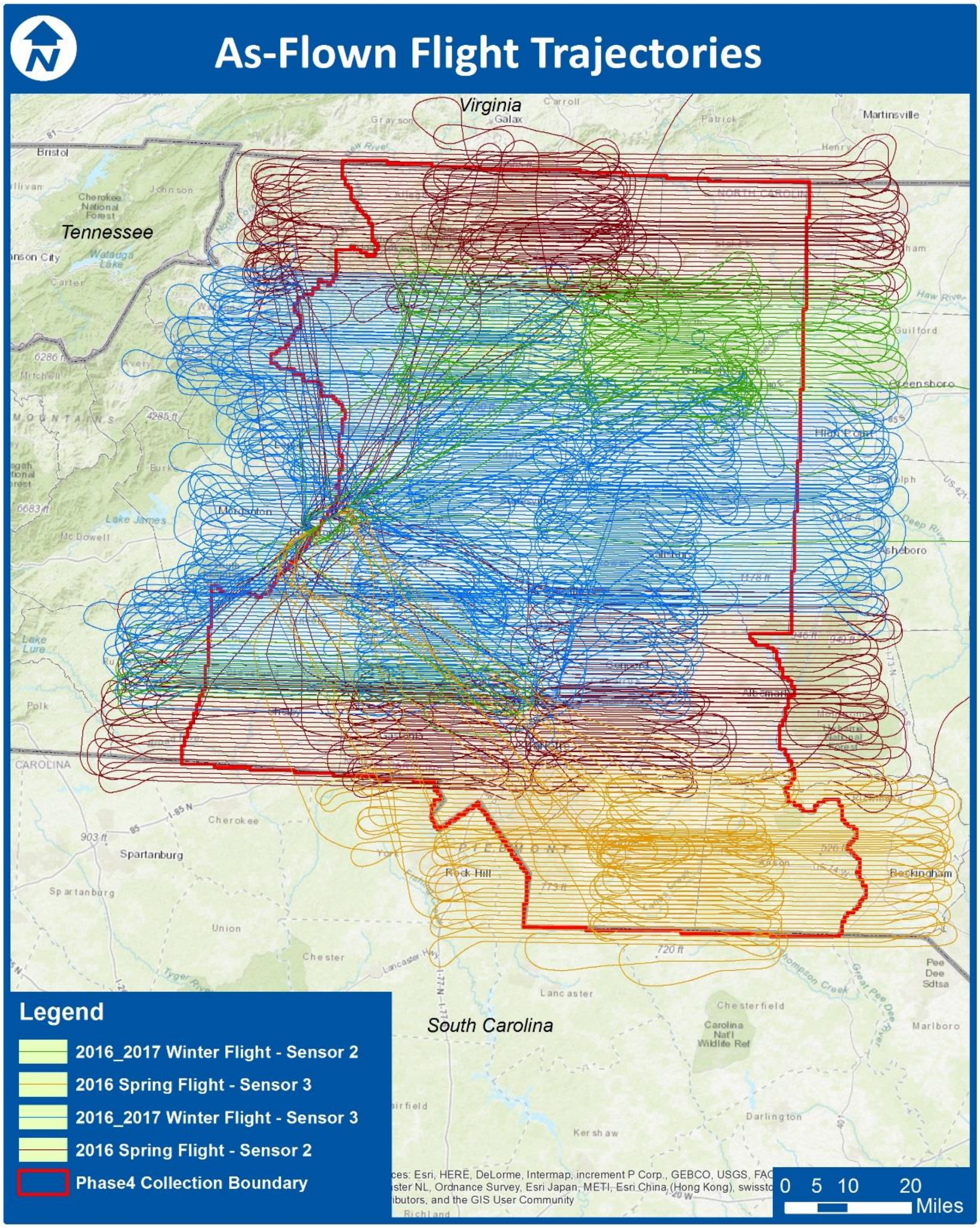
Table 3: Used aircraft.

Make/Model	Tail Number	Type	Ceiling
Cessna A200	N46L	Twin-Piston	33,000’
Cessna A200	N49R	Twin-Piston	33,000’
Cessna A200	N40R	Twin-Piston	33,000’

2.3 – As-Flown Flight Lines

Figure 3 portrays the as-flown flight lines for the project for the data collected. Flight lines are colored by sensor number (2 or 3) as well as by whether the lines were collected in the 2016 spring timeframe or 2016-2017 winter timeframe. As-flown trajectory files in ESRI shapefile and Google KML format have been provided to the NCEM as an attachment to this report.

Figure 3: Overview of project "as-flown" lines.



2.4 – Flight Dates

Appendix A outlines the flight activity for each day of the collection periods, between the acquisition dates of February 27, 2016 and April 17, 2016 and between December 9, 2016 and February 21 of 2017. Tables in Appendix A includes comments and any reflight information. The GmAPD sensor operator is able to view a low resolution, real-time display of the data being collected, allowing for most reflights to be identified inflight and then collected the same night. Very few reflights with the GmAPD sensor necessitated a reflight of lines outside of the original collection date. Flight logs and the Daily Activity Report for each day are included in the digital attachments for this report.

2.5 – Collection Environment

Acquisition was performed under leaf-off conditions during the winter/spring of 2016 (February-April) and the winter of 2016/2017. Acquisition commenced with the approval of the NCEM. Table 4 illustrates the Project's specifications for acquisition:

Table 4: Acquisition conditions.

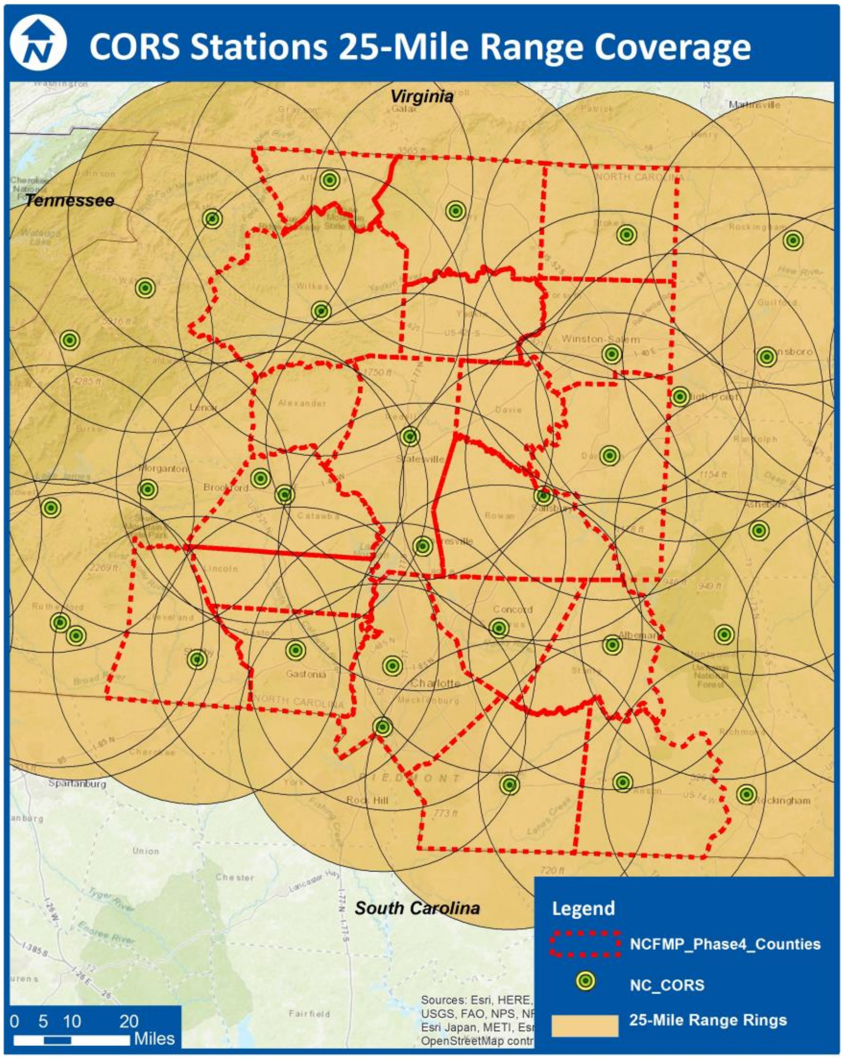
Parameter	Specification
Acquisition Dates	Winter of 2015-16(Feb – end of leaf off conditions)
	April 17 was the cut-off date based on observed ground conditions
	Winter of 2016-17
	No cut-off date; project was completed within leaf-off window
Atmospheric Conditions	Cloud and fog free
	Snow free (light, un-drifted snow may be acceptable)
	No unusual flooding or inundation
	Leaf-off and no cloud cover
	*All conditions were coordinated with the NCEM
Tidal Conditions	None for this geographic area

Acquisition each day was subject to carefully monitored weather and ground conditions. Non-flight days due to weather conditions are documented in the daily flight tables in Appendix A of this report. PDF documents containing field pictures of ground conditions after a snow event and depicting leaf off condition during the end of the flight season, are also included as digital attachments to this report.

2.6 – GPS Base Station Information

As illustrated in Figure 4, roving base stations were not required due to the dense Continuously Operating Reference Station (CORS) network in the State of North Carolina. This figure portrays the 1-second frequency CORS stations with a 25-mile radius. As can be seen, the program requirement to maintain less than 50 km (31 miles) from each base station was easily satisfied using the existing network.

Figure 4: Existing CORS Station Map



2.7 – Airport Operations

The ESP team utilized the airport shown in Table 5 and Figure 5 for the base of operation for the aircraft utilized in the LiDAR acquisition. This particular airport was selected based on the availability of support facilities and location which allowed for effective mobilization to project acquisition areas

Table 5: Airport base of operations

Airport	Location	Designation
Hickory Regional Airport	Hickory, NC	KHKY

Figure 5: Airport base of operations

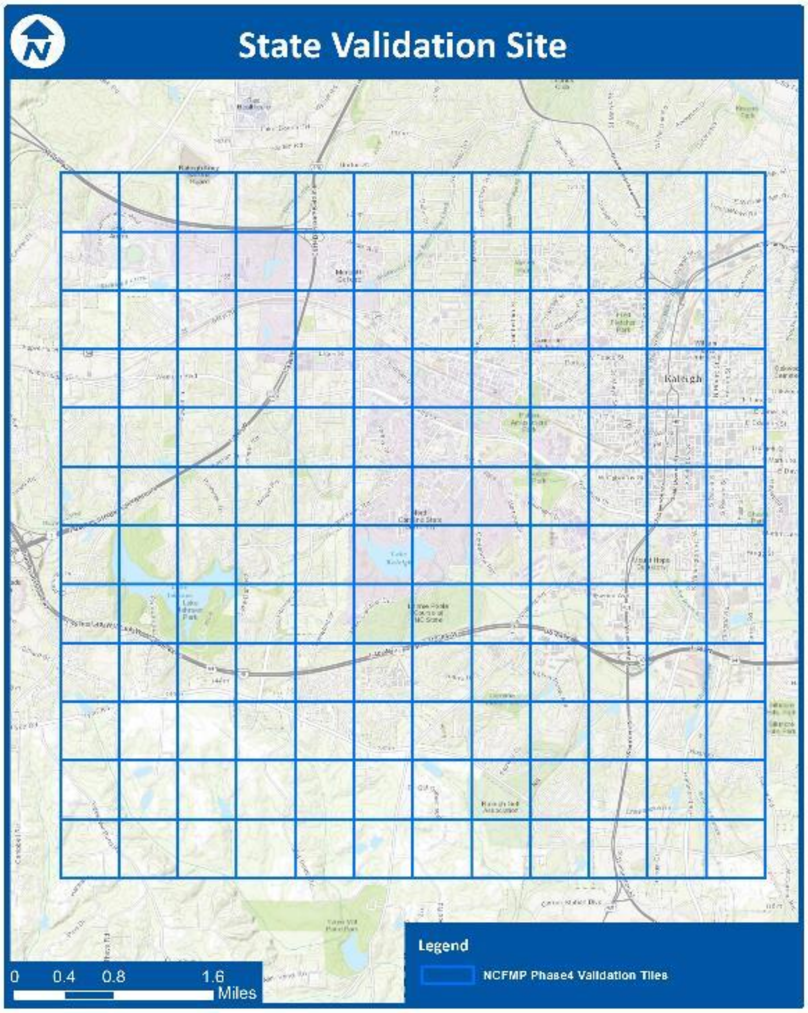
2.8 – Airspace Restrictions

This project area did not encompass any Military Operations Areas (MOAs). Any potential restricted air spaces were managed by Harris during acquisition.

2.9 – Initial Validation and Calibration Site

The State LiDAR validation range located within Raleigh, NC was used to validate each LiDAR sensor before use on the program. This area was comprised of a good balance of scene content, including vegetated areas, bodies of water, and cultural detail. It involved 144, 2,500' x 2,500' tiles as depicted in Figure 6. Each sensor was flown over the validation range prior to use and the acquired data and processed data quality controlled and delivered to the NCEM for approval. Furthermore, sensors were flown over the validation range after any upgrades or repairs to sensors and prior to resuming collection activities. As an evolving technology, the sensors underwent several upgrades/improvements to the system during this project.

Figure 6: InSitu validation range



2.10 – Re-Flight Procedures

During data acquisition, the flight crews were provided with up-to-date flight plans that illustrated progress to date, lines left to acquire, and lines left to re-fly based on internal inspection results. In most cases, re-flights were identified inflight and were recollected the same night. The ability of the crew to review a real-time “waterfall” depiction of the data during collection facilitated the reflight of lines during the same mobilization.

At the end of each night, the aircrew reported progress for the night to ESP for ingestion into the tracking site. The information was coupled with the results of inspection to generate plans for the following day. This consisted of noting which lines were acquired and additional information that may indicate a re-flight was necessary (such as extreme turbulence or winds, clouds, ABGPS and/or equipment warnings/failures, etc.).

2.11 – Calibration Procedures

Once an overall QA of the acquired flights was completed, the areas approved were released to the calibration team at Harris. For this project, Harris was responsible for conducting the calibration task for all data as the raw format of the GmAPD is proprietary.

The calibration of GmAPD LiDAR data is similar to the aerotriangulation process used in photogrammetry, and therefore offers a robust solution to achieving high accuracy at altitudes exceeding the limitations of linear sensors. During initial processing of GmAPD data, internal point cloud geometry (precision) is greatly improved throughout the entire point cloud in all three axes with no manual intervention relying only on robust mathematical equations to solve for errors. Tie points are generated by automatically matching ground feature between different swaths. These tie points are then used in conjunction with manually identified survey ground control points in a sensor model based bundle adjustment process to refine the GPS SBET solution. The data is then retransformed from sensor to ground space using this updated SBET and filtered to produce the final solution which supports USGS QL1 accuracy specifications.

The calibration process and results were under the oversight of a North Carolina Professional Land Surveyor. Additional information on the calibration process, internal verifications, and independent accuracy tests is included in the Post-Processing Report for this project.

3.0 – Overview of Data Calibration Process

This section of the Post-Acquisition report covers the processes for ground surveys in support of calibration and general calibration processes.

3.1 – Ground Control Survey for Calibration

For the LiDAR calibration point surveys, the goal was to provide horizontal and vertical positions on hard surface, urban land cover points. Bare-earth/low grass points were considered as an alternative in areas where a suitable hard surface point could not be found. Field procedures were consistent with the National Geodetic Survey Guidelines for Real Time GNSS Networks, March 2011, v.2.0. These procedures included making redundant occupations under different satellite configurations and field conditions for each point.

The calibration points were spread throughout the collection area in accordance to the project point layout plan. Close attention was paid to the LiDAR acquisition area boundaries in order to avoid surveying points that could fall outside the collection area. Due to the separate acquisition timeframes, the ground control points were only surveyed during active flight operations to avoid any potential issues caused by temporal differences.

ESP collected 478 well-distributed GPS survey control points to supplement ABGPS accuracy. Each location was double occupied to validate accuracy. No control panels were placed as part of this effort. This control was used to facilitate calibration of LiDAR flight lines/blocks, perform mean adjustment, and test final fundamental accuracy of the data. The vertical accuracy checkpoints adhered to the following guidelines:

1. Located only in open terrain where there is a high probability that the sensor will have detected the ground surface without influence from surrounding vegetation.

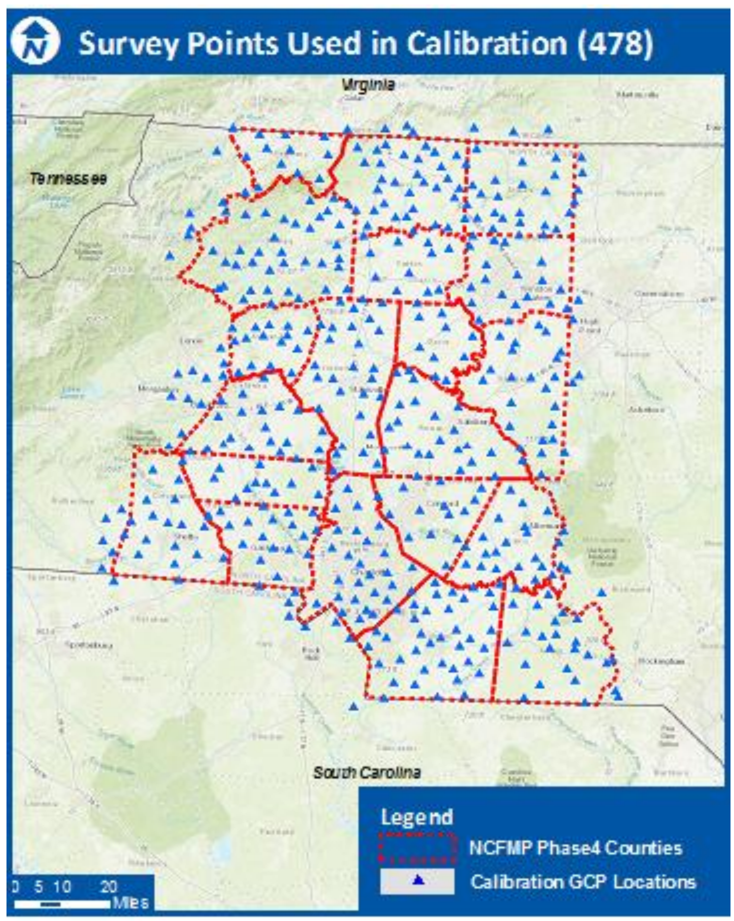
2. On flat or uniformly sloping terrain at least five (5) meters away from any breakline where there is a change in slope.
3. Checkpoint accuracy shall satisfy a Local Network accuracy of 5 cm at the 95% confidence level.
4. Some points will be collected on elevated, photo-identifiable features based on the calibration process of the Geiger-mode LiDAR.

An example of an above-ground, photo-identifiable points is provided in Figure 7.

Figure 7: Elevated, photo-identifiable feature

Unique to this team's LiDAR technology is the calibration process of the Geiger-mode sensors. This calibration process is proprietary to team member Harris and incorporates the ability to use aboveground, identifiable features for the calibration. A portion of the survey points used in the calibration were located on photo-identifiable, permanent above-ground objects that can readily be seen from multiple angles in the data. Figure 8 depicts the distribution and location of the collected survey points.

Figure 8: Calibration survey point locations



3.2 – Ground Control Collection Procedures

The following LiDAR calibration control point procedure was followed by the survey crews on the project:

- Double occupy all LiDAR calibration points after a 2+ hour split to ensure that the occupations occur during different satellite configurations and field conditions. The results of the different observations must check within 5 cm (0.16’) both horizontally and vertically at the 95% confidence level.
- Take care to ensure that points are located in suitable locations that ensure that the LiDAR collection will get a good return.
    - In urban areas, avoid new asphalt or other dark areas. Highly reflective marking on the pavement can be used but avoid areas where vehicles may be parked. Large concrete areas would be ideal for calibration points due to high reflectivity.
    - Locations need to be in a flat or uniformly sloping area - avoid breaklines (curbs, top/toe of slopes, ditches, etc.) and any other obstructions to the ground surface (roots, fallen trees, etc.) in a 5-meter (15 – 20 ft.) radius of the point.
    - If the ground surface is soft, ensure that the point collected is flush with the ground surface (rod doesn’t sink below)
    - Points set on the ground must be marked with a PK nail or 60D nail (or larger)
    - If elevated, photo-identifiable features are used they must follow the guidelines developed by ESP and Harris.
- When proving photo documentation of LiDAR calibration points:
    - Take 2 photos for each calibration point (1 facing North and 1 facing East) – each photo should be at taken at 90-degree angles from one another towards the calibration point.
    - Take the picture close enough to identify the calibration point, but yet far enough away to identify the surrounding features within the vicinity of the point. (Approximately 20 to 25 feet should suffice). The GPS rover occupying the point must be visible in all photos.
    - Make sure the LiDAR calibration point identifier (#) is visible in the photos as well using a dry easer board– this will ensure that photos will be renamed accurately.
    - Name the photos according to the direction in which they are taken, i.e. ESP001_North and ESP001_East.

The North Carolina Geodetic Survey Real-Time Network will be used for primary control for LiDAR calibration point surveys. Static GPS procedures will be used in cell coverage gap areas. The horizontal datum will reference NAD83/2011 Epoch 2010.00 and elevations will reference NAVD88 and use the Geoid12B model to determine orthometric heights.

To verify the horizontal positions and GPS derived orthometric heights, published NGS bench marks will be checked throughout the survey area. Each NGS bench mark tie will follow these procedures:

- For each benchmark recovered, take 2 photographs: 1) A close-up view of the disc 2) A view of the rover occupying the monument that shows the surrounding area.

4.0 – Quality Control

This section of the Flight Operations Plan will cover the quality control procedures followed during acquisition as well as during a review of all flight data. Procedures and review of post-calibrated data will be included in the final Post-Acquisition Report.

4.1 – Flight Mission Checklist

Harris was required to complete a Flight Mission Checklist that details general information for both Pre-flight and In-flight requirements. This ensured that a consistent quality control step process was followed prior to each flight. The flight mission checklists were incorporated as part of the flight logs and are included as digital attachments to this report.

4.2– Data Verification and Transfer

Upon completion of each mission, each aircrew executed additional responsibilities. First, they verified the integrity of the ABPS/IMU and LiDAR data to ensure that a successful capture occurred. This step entailed using instrument-specific procedures and software. Next, a backup of all data occurred onto two independent transfer drives and the drives were shipped back to the Harris production office as soon as possible.

In addition, each mission day had an associated Daily Activity Report that was sent by every aircrew at the end of each acquisition day to the Flight Operations Manager. This reduced or eliminated the potential for lost or corrupt data transfers during the acquisition phase. The Daily Activity Reports generated for this project have been included with the digital file package submitted with this report.

4.3– Flight Data QA/QC

Post-acquisition QA/QC steps at ESP occurred as data were calibrated and delivered for the project. Initial QA/QC of as-flown data by ESP was limited to the review of flight reporting and trajectory files until data were delivered.

Once data were received they were checked in accordance with the NC LiDAR Standard and internal QA/QC processes, and steps were taken to verify that the flown data were complete and ready for ingestion into the production workflow.

Once calibrated data were delivered, the data packages underwent a further, in-depth review. Both pre- and post-calibration reviews are outlined in Table 6. Entries in blue denote checks that occurred on calibrated data once delivered.

Table 6: Post-Acquisition QA/QC Matrix.

QA/QC Step	Comments	Corresponding Standard/Specification
1. Data completeness	Deliverable media is readable; all files for flight are present, no gross gaps, cross flights are present	Internal
2. Check against flight plan	Trajectory files are reviewed to ensure flight plan was followed	Internal
3. Flight parameters	Sensor settings and flight reflect the approved project design	Internal

QA/QC Step	Comments	Corresponding Standard/Specification
4. Data coverage	Data covers planned collection; areas along project boundary and 100' buffer are adequately covered	Contractual
5. Data voids	$\leq$ 4*Aggregate Nominal Pulse Spacing (ANPS) except where caused by water bodies, low reflectivity, or is filled by another swath/lift	NC LiDAR Standard Section 5.01.4
6. GPS & IMU	Reviewed to ensure proper operation/coverage/quality (includes base stations)	Internal and NC LiDAR Standards, Sections 5.02.4 and 6
7. Density	Review of density to verify nominal pulse spacing (NPS) is 0.35 meter or better	Contractual
8. Intensity	Intensity values are present and consistent in range	NC LiDAR Standard Section 5.01.2
9. Overlap	Overlap between adjacent lines is 10% or better	Geiger is flown at 50% or better

Verification that proper environmental conditions were met during data collection was accomplished by reviewing flight logs and monitoring weather and ground conditions

4.3– Data Calibration QA/QC

Calibrated blocks were shipped to ESP for an accuracy review that was independent of the calibration process. This QA/QC review consisted of automated and manual testing methods to ensure the quality of the data and the adherence of the data to the project specifications. The review included, but was not limited to, the following key QA steps:

- Data integrity check
- Coverage and void check
- Internal vertical accuracy check
- Review of intensity values/quality
- Data density and distribution check

4.3.1– Data Integrity Check

To ensure that all data received by ESP was intact an initial review was conducted on each shipment to check for abnormally sized, corrupt, or missing files. After this initial review, the integrity and completeness of each LAS tile record was checked using an automated tool reporting the following attributes for each tile:

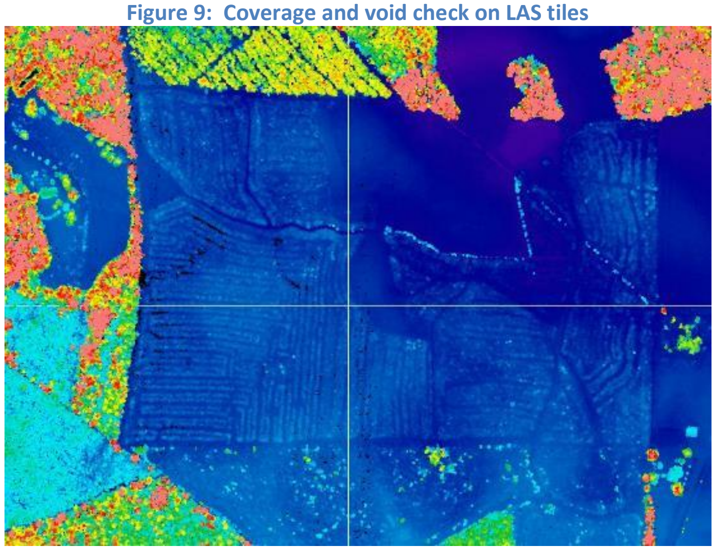
Table 7: Overview of automated LAS record content report.

Report Contents		
Project ID 1	Minor Version	Y Limits (actual)
Project ID 2	Number of Variable Length Records	Z Limits (header)
Project ID 3	Record Type	Z Limits (actual)
Generating Software	Number of Records	X/Y/Z Scale
Creation Day	Intensity	X/Y/Z Offset
Creation Year	Angle	Source File ID
Global Encoding	Major Version	X Limits (header)
X Limits (actual)	Y Limits (header)	

4.3.2– Coverage and Void Check

Upon receipt of calibrated data, the data were checked for any potential coverage or unacceptable voids at several stages in the QA process. The initial review was done by visually inspecting the data to ensure that any voids were acceptable (such as those caused by water bodies) and that the coverage encompassed the full extents of the project tile layout.

Figure 9: Coverage and void check on LAS tiles



The data were also reviewed for coverage and gaps when conducting other QA steps such as relative accuracy checks and review of intensity values. This ensured a redundant approach of review to reduce or eliminate the potential for error.

4.3.3– ABGPS and IMU Review

During acquisition, monitoring ensured that proper Airborne GPS (ABGPS) surveying techniques were followed (including pre-and post-mission static initializations) and in-air Inertial Measurement Unit (IMU) alignment (proper self-calibration of IMU accelerometers and gyros) was conducted. After acquisition, as-flown trajectories and ABGPS quality plots were reviewed to ensure that no potential issues were missed and that all lines were flown to plan. ABGPS quality plots are included as part of the digital deliverable for this report.

4.3.4– Relative Accuracy Check

GmAPD LiDAR is calibrated across a block as a single point cloud as the processing of Geiger Mode data is different than linear mode systems. Data products are built (aggregated) from multiple data frames captured from multiple look angles. As a result of this process there are no associated flight lines in the output data sets. All data are aggregated into the final output tiles as a seamless dataset. No flight line (Point Source) record labels exist since final data are built from four (4) look fully aggregated point sets from all flight lines. In addition to not containing discrete line identifications during calibration, the swaths contain 55% overlap for this project design. A relative accuracy check is not possible, nor necessary, for this project.

4.3.5– Internal Vertical Accuracy Check

Though a truly independent vertical accuracy check was conducted by a third party contracted by the NCEM, the ESP team conducted two internal checks of the vertical accuracy based on limited, existing control and some additional control collected by ESP. The first check was to compare the calibrated LiDAR against the calibration control points for the project. This check ensured that, at a minimum, the data was adjusted to the correct survey points provided for that task.

The second check was to compare the calibrated LiDAR against any existing and additionally collected survey points within the project area that were located in open terrain. In both cases, only open terrain could be assessed as the data was not classified to ground until later in the production process. Any variances between the calibrated LiDAR surface and available survey points were investigated to determine the source of the variance. In most cases variances were acceptable and explained by:

- Temporal differences (changes in terrain surface due to construction or other factors since the survey control was acquired)
- Placement of a survey point near sloping terrain or breaks in terrain which could skew results

4.3.6– Data Density and Distribution Check

Data density and distribution were measured against the project specifications to ensure that the project Aggregate Nominal Post Spacing (NPS) of 0.35-meters was met or exceeded, that no unacceptable data voids greater than (4*ANPS)2 existed, and that spatial distribution was uniform.

Using proprietary software, ESP tested the NPS and spatial distribution and reviewed the data. The software generates a density raster as well as a Microsoft Excel file outlining the density and distribution measurement results. For density, the criterion to meet was to find at least four points per square meter. For distribution, a grid of cells was used where each cell is equal to 2*ANPS and the cells were polled to ensure that 90% or more of the cells contained at least 1 LiDAR point.

4.3.7– Review of Intensity Values and Quality

Intensity values were inspected across block deliveries to ensure that no anomalous ranges of values are present and to ensure that it would be possible to achieve a minimal level of homogeneity across the project during the production phase. The intensity values of each delivery were visually inspected at the block level and sample histograms were processed to review the actual range of values present in a given area.

5.0 – Recommendations for Future Projects

This section contains recommendations for future data collection activities under this program.

1. With the proven calibration results of the latest LiDAR sensor technology, we recommend that the NCEM no longer specify the calibration methods outlined in Appendix G: Daily Calibration Survey / Boresight Calibration of the North Carolina Technical Specifications for LiDAR Base Mapping.
2. For future projects, the GPS quality plots for each sortie will be standardized

Data Acquisition Controls Reviewed and Report Prepared by:

Harold Rempel, CP, GISP

American Society for Photogrammetry and Remote Sensing
HAROLD REMPEL
CERTIFIED
PHOTOGRAMMETRIST
(ASPRS) No. R1418
Exp. 2/21/2019

09/19/17

Internal vertical accuracy assessment outlined in

In Section 4.3.5 of this report reviewed and approved by:

James C. Gray Jr., PLS

NORTH CAROLINA
PROFESSIONAL
SEAL
L-4778
LAND SURVEYOR
JAMES C. GRAY, JR.

09/19/17

NORTH CAROLINA
LICENSE NO.
C-0587
ESP ASSOCIATES, P.A.

Post-Acquisition Report

Appendices

Appendix A – Flight Dates

Harris was approved to start data acquisition on February 17, 2016, however flights did not commence until February 27th due to weather, mobilization, and timing of the project kick off. The duration of the spring collection window lasted 51 days of which 22 were flight days (the remaining 29 days were non-flight days due to inclement weather, high winds aloft, or other issues).

Daily Flight Status – Spring Collection		
Window Date	**Flight Progress**	**Comments**
27-Feb-16	Validation Site	N/A
28-Feb-16	No flight - processing validation	N/A
29-Feb-16	No flight - processing validation	N/A
1-Mar-16	No flight - processing validation	N/A
2-Mar-16	No flight - processing validation	N/A
3-Mar-16	No flight - cloud cover	N/A
4-Mar-16	No flight - cloud cover	N/A
5-Mar-16	No flight - cloud cover	N/A
6-Mar-16	No flight - cloud cover	N/A
7-Mar-16	No flight - cloud cover	N/A
8-Mar-16	Relfight of validation with new settings	Yes, of entire site
9-Mar-16	Relfight of validation with new settings	Yes, of entire site
10-Mar-16	No flight - weather & plane repair	N/A
11-Mar-16	Relfight of validation with new settings	Yes, of entire site
12-Mar-16	No flight - processing validation	N/A
13-Mar-16	No flight - weather	N/A
14-Mar-16	No flight - weather	N/A
15-Mar-16	Block 24	Lines 839,842,844-861 Line 847 tagged for reflight
16-Mar-16	Blocks 24 (completed) & 23	BLK 24 - 841,838,843,840,837,836 & BLK 23 810-820,822,825 (812 reflown)
17-Mar-16	No flight - high winds	N/A
18-Mar-16	No flight - high winds & clouds	N/A
19-Mar-16	No flight - Cloud cover	N/A
20-Mar-16	No flight - Cloud cover	N/A
21-Mar-16	Blocks 23 (completed) & 22	BLK 23 - 823, 826, 821, 824, 827, 830-835 828, 829 BLK 22 - 792-801, 804
22-Mar-16	Blocks 22 (completed) & 21	BLK 22 - 802, 803, 805-809 & BLK 21 - 774-780, 781-784, 786, 789, 787
23-Mar-16	Blocks 21 (completed) & 20	BLK 21 - 790, 785, 788, 791 & BLK 20 - 752,755,750
24-Mar-16	No flight - sensor repair	N/A
25-Mar-16	No flight - sensor repair	N/A
26-Mar-16	No flight - sensor repair	N/A
27-Mar-16	No flight - sensor repair	N/A

28-Mar-16	Blocks 20 and Validation Site	Validation site & BLK 20 - 750 to test wind conditions. Bad winds.
29-Mar-16	Blocks 20 (completed) & 19	BLK 20 - 751, 753-754, 756-773 & BLK 19 - 726-733, 736
30-Mar-16	No flight - weather	N/A
31-Mar-16	No flight - weather	N/A
1-Apr-16	No flight - weather	N/A
2-Apr-16	Blocks 19 (completed) & 15	BLK 19 - 734-735,737-749 & BLK 15 - 326-328,331,333
3-Apr-16	Block 18	419,416,413,410,407,412,409, 406,411,408
4-Apr-16	Blocks 18 & 17	BLK 18 - 414-415,417-418,420-422,424-425,427 & BLK 17 - 379
5-Apr-16	Blocks 18 (completed) & 17 (all -1 line)	BLK18 - 423,426,429 & BLK 17 - 380-401, 403, 404
6-Apr-16	No flight - weather	N/A
7-Apr-16	No flight - weather	N/A
8-Apr-16	No flight - weather	N/A
9-Apr-16	Block 1	988, 989, 990x2, 992, 993, 994, - camera malfunction
10-Apr-16	No flight - Cloud cover	N/A
11-Apr-16	No flight - Cloud cover	N/A
12-Apr-16	Block 1	0999, 0001, 0002, 0005, 0006, 0008 - camera malfunction
13-Apr-16	Block 3	0044-0061
14-Apr-16	Block 2	0023-0030
15-Apr-16	Blocks 2 & 1	BLK 2 - 0031-0043 & BLK 1 - 0009
16-Apr-16	Block 1	0004, 0007, 0013-0015, 0021, 0022, 0020 and all reflight lines for BLK 1
17-Apr-16	BLKS 1, 2 & 3 (all completed)	All remaining reflights for these blocks collected

Daily Flight Status – Winter Collection		
Window Date	**Flight Progress**	**Comments**
09-Dec-16	Validation site collection for sensor 3	Validation site collect good
10-Dec-16	Block 4	1392-1401, 1403,1406
11-Dec-16	No flight - weather	N/A
12-Dec-16	Blocks 4 (all complete) & 5	BLK 4 – 1402, 1404,1405, 1407-1412 & BLK 5- 1413-1420, 1424, 1427
13-Dec-16	No flight - processing validation	N/A
14-Dec-16	No flight - weather	N/A
15-Dec-16	No flight - weather	N/A
16-Dec-16	No flight - cloud cover	N/A
17-Dec-16	No flight - cloud cover	N/A
18-Dec-16	No flight - cloud cover	N/A
19-Dec-16	No flight - cloud cover	N/A
20-Dec-16	Validation site for sensor 2, Blocks 7, 5 (all complete) & 8	Validation site clear, BLK 7 – 1872-1889, 1894 & BLK 5 – 1422-1432 & BLK 8 1511, 514-1517

21-Dec-16	Blocks 7 & 9	BLK 7 – 1892-1901 Line 1897 tagged for reflight & BLK 9 – 1518 & 1521
22-Dec-16	Blocks 7 (all complete) , 6, 15, 8 (all complete) & 9	BLK 7 – 1897 & BLK 6 – 1867 & BLK 15 – 2121-2130, 2132, 2135 & BLK 8 – 1498-1512 & BLK 9 – 1521, 1528, 1531, 1534-1538
23-26-Dec	Christmas Break	No Flights
27-Dec-16	Block 6	1850-1871
28-Dec-16	Blocks 6 (all complete), 9 (all complete), 10 (all complete) & 12	BLK6 – 1841 – 1849, 1852, 1855 & BLK 10 – 1956 & BLK 9 – 1519 – 1520, 1522 – 1527, 1529-1530, 1532 & BLK 12 – 2343, 2345-2346
29-Dec-16	No flight - weather	N/A
30-Dec-16	Blocks 12 & 15	BLK 12 – 2323 – 2345 & BLK 15 – 2141 - 2151
31-Dec-16	Holiday	N/A
1-Jan-17	Holiday	N/A
2-Jan-17	No flight - weather	N/A
3-Jan-17	No flight - weather	N/A
4-Jan-17	No flight - weather	N/A
5-Jan-17	No flight - weather	N/A
6-Jan-17	No flight - weather	N/A
7-Jan-17	No flight - weather	N/A
8-Jan-17	No flight - weather	N/A
9-Jan-17	No flight - weather	N/A
10-Jan-17	No flight - weather	N/A
11-Jan-17	No flight - weather	N/A
12-Jan-17	No flight - weather	N/A
13-Jan-17	No flight - weather	N/A
14-Jan-17	No flight - weather	N/A
15-Jan-17	No flight - weather	N/A
16-Jan-17	No flight - weather	N/A
17-Jan-17	No flight - weather	N/A
18-Jan-17	Blocks 12 & 15	BLK 12 – 2314 – 2322, 2349, 2355 & BLK 15 – 2372 - 2380
19-Jan-17	No flight – weather	N/A
20-Jan-17	No flight – weather	N/A
21-Jan-17	No flight – weather	N/A
22-Jan-17	No flight – weather	N/A
23-Jan-17	No flight – weather	N/A
24-Jan-17	Blocks 10 & 15 & Validation Site	Tested camera repair, BLK 10 – 4207, 4210-4215 & BLK 15 – 2347, 2350, 2362, 2364-2371
25-Jan-17	No flight – weather	N/A
26-Jan-17	Block 15	2348, 2351, 2353-2354, 2356-2361, 2363
27-Jan-17	Blocks 11 & 14	BLK 11 – 2193, 2198, 2200-2206, 2211 – 2215 & BLK 14 – 2266, 2269, 2272 - 2281

28-Jan-17	Blocks 11(all complete) & 14	BLK 11 – 2184-2197, 2199 & BLK 14 – 2248-2249, 2251-2252, 2254-2255, 2258, 2261, 2264-2265, 2267-2268, 2270-2271
29-Jan-17	No flight – weather	N/A
30-Jan-17	Blocks 13 & 14 (all complete)	BLK 13 – 2216-2232, 2235, 2238 & BLK 14 – 2250, 2253, 2255-2257, 2259-2260, 2262-2263
31-Jan-17	Blocks 13 (all complete) & 16	BLK 13 – 2233, 2236. 2239, 2234, 2237, 3340-2247 & BLK 16 – 2298, 2300-2313
1-Feb-17	Block 16	2282 - 2299
2-Feb-17	No flight – weather	N/A
3-Feb-17	Blocks 10, 11(all complete) & 16 (all complete)	BLK 10 – 1561-1562 & BLK 11 – 2207-2210 & BLK 16 – 2308, 2310, 2313
4-Feb-17	Block 10	1537, 1548 – 1560, 1563
5-Feb-17	Blocks 10 (all complete), 12 & 15 (all complete)	BLK 10 – 1538 – 1547, 1564 – 1569 & BLK 12 – 2315-2316 & BLK 15 – 2349, 2355, 2372 - 2380
6-Feb-17	No flight – weather	N/A
7-Feb-17	No flight – weather	N/A
8-Feb-17	No flight – weather	N/A
9-Feb-17	Block 12 (all complete)	2317-2322

Appendix B – Digital Attachments

The following digital attachments have been provided as part of this report:

- Daily_Activity_Reports: contains the archive of all Daily Activity Reports submitted to ESP by the acquisition team during flight operations (PDF format)
- Flight_Logs: contains all flight logs generated for this project (PDF format)
- GPS Quality Plots: contains the GPS quality plots associated with each lift of data, by Block (PNG or BMP)
- Trajectory files: contains as-flown trajectories for each sensor serial # (Google KML and ESRI Shapefile format)
- Ground Condition Checks: this folder contains two PDF files with field photos showing leaf-off conditions during the end of the 2016 collect and snow conditions within the project area during the winter collect