STARR
Strategic Alliance for Risk Reduction

Kittitas

Pre-Flight Operations Plan

November 2010

Introduction

The following is the Pre-Flight Operations Plan for the Washington (FEMA Region 10) Kittitas project area. The report will cover GPS, control plans, airport locations and Aircraft used, calibration procedures as preformed by Aero-Metric, quality procedures, and procedures for tracking, executing and checking for re-flights. The planning of the project was based on the scope of work provided, FEMA Procedure Memorandum No. 61, and the USGS NGP V 13 specifications.

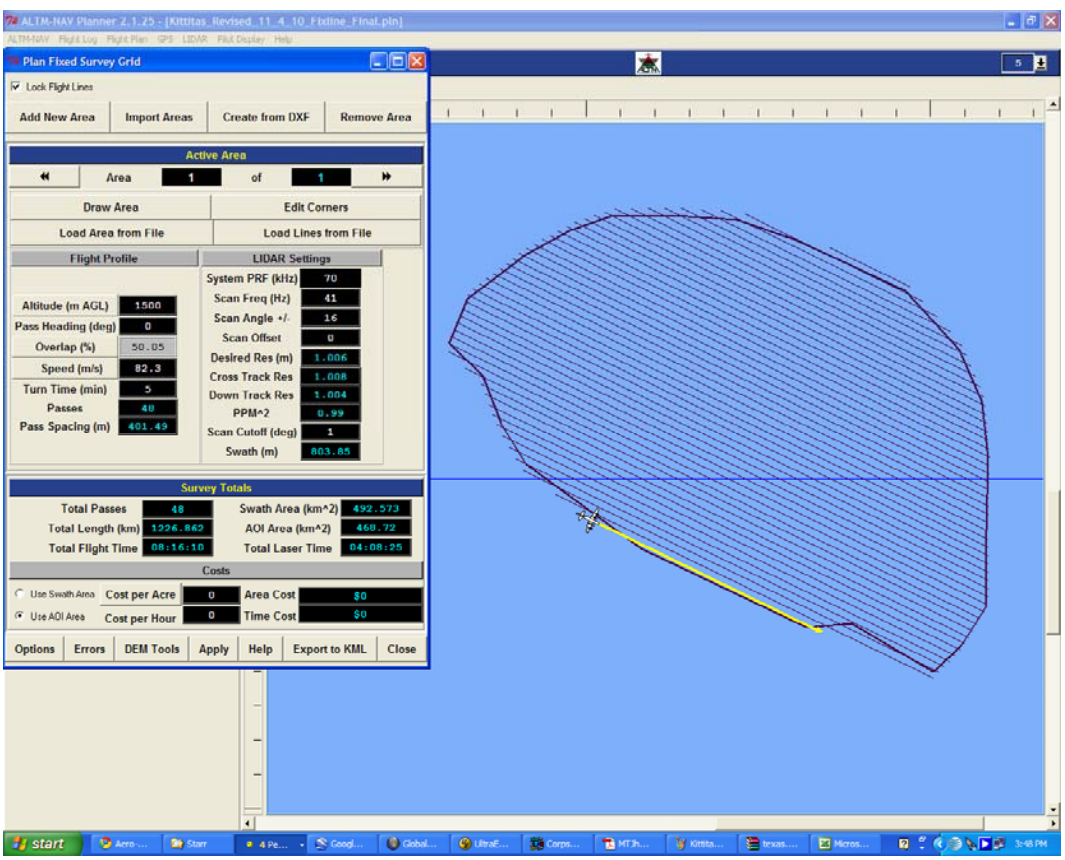
Airport Locations and Type of Aircraft Used

The airport locations for the Kittitas project area are Bower Field (KELN), Pangborn Memorial (KEAT), Yakima (KYKM), Grand County (KMWH), Richland (KRLD), Ephrata Municipal (KEPH) airports. All airports should be suitable for base of operation and have suitable SAC\PAC GPS points. The exact location for base of operation will be determined based on the requirements of the aircraft selected for the collection. In addition, the airport hours of operation will be an important determining factor for planning the LiDAR collection.

Aero-Metric has 4 LiDAR Aircraft used for LiDAR. The aircraft used by Aero-Metric use for LiDAR are an Aztec, Navaho and Twin Commander 500s which are twin engine aircraft and a Cessna 210 which is a single engine aircraft. The tail numbers for these aircraft are N3443Q, N73TM, N280MB and N69WA, respectively.

Project Flight Plans

The following are the flight plans for the Kittitas Project area. The plans below detail the LiDAR collection parameters and flight lines as represented in the ALTM_NAV software used during collection of the project areas.



GPS Stations (base stations)

The GPS stations will be selected based on the list of points provided below. The exact points for this collection are not detailed since the current recovery data may not be valid. Therefore the location of base stations will be assessed once on site based on the reliability of the given point(s). All points on the list are suitable for GPS observations and will be provided to the field staff.

PID	LATITUDE	LONGITUDE	Horizontal	Vertical
Kittitas				
CO6017	47 00 01.19035	120 32 18.54665	A	H
AH2506	47 00 01.19017	120 32 18.54694	A	H
AJ7207	46 57 03.31176	120 43 28.53658	A	H
DL3300	46 36 17.85473	120 30 18.17383	A	H
SX1079	47 00 43.35100	120 31 16.2824	0	1
AI3654	47 00 15.32732	120 31 39.47645	0	1
AD9543	47 02 26.02395	120 32 05.79785	0	
SX1547	47 01 51.11424	120 31 14.92835	0	
AA6011	47 02 11.64953	120 29 52.47812	0	

In the event that Aero-Metric has to establish a new point the information of the new point or points will be provided.

LiDAR System Calibration

As part of every LiDAR project, Aero-Metric performs system calibration upon sensor installation and at three month intervals in the event the LiDAR system remains in the aircraft. The system calibration is performed to identify inconsistencies between the software corrections as they relate to the sensor hardware and its relationship to the GPS antenna location on the aircraft. Typically, a series of calibration lines (*figure 1*) are flown over a test range at verified attitudes to validate the calibration of the LiDAR sensor. The Aero-Metric team's main calibration sites include the following locations: Sheboygan County Airport in Sheboygan, Wisconsin, Boeing Field in Seattle, Washington and Merrill Field in Anchorage, Alaska.

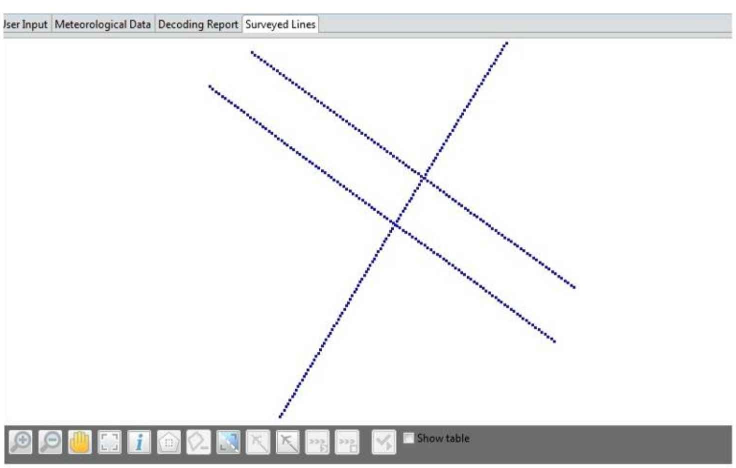


Figure 1: System LiDAR Calibration Configuration

The system calibration is preformed to validate and maintain the error budget associated with the Inertial Measurement Unit (IMU), mirror angle encoding, and pulse gate timing. In simple terms we correct the variations in roll, pitch, heading, scale scan factor and Z- bias as a result of the changes in the system information. The results of the calibration contribute to the tuning of the sensor prior to deployment of the LiDAR and aircraft to a project location.

Aero-Metric uses an innovative approach to calibration. The variables showing historic stability are held in the calibration process and variables such as roll are floated and redefined using the planar surfaces, or tie planes. The least squared adjustment is applied to the differences associated with the LiDAR data and the results are analyzed to provide consistence throughout the calibration and resulting data sets. In addition roof lines and roof surfaces are evaluated to further refine the calibration. The representation in Figure 2 depicts the tie planes of the calibration referenced above in figure 1.

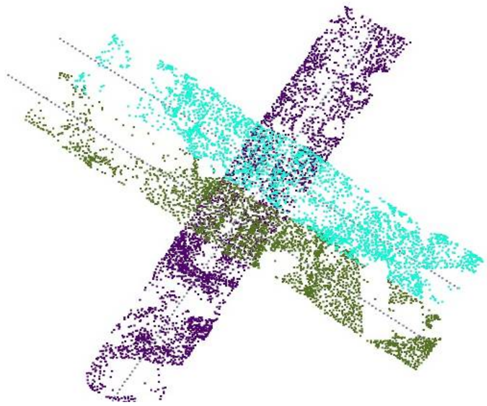


Figure 2: Tie plane depiction of calibration

ALS-ID	scan-offset		scan-scale		scan-lag	
	value [deg]	std.dev. [deg]	value [-]	std.dev. [-]	value [deg]	std.dev. [deg]
SC1	-	-	0.000090	0.000018	0.000335	0.000056

ALS-ID	Ex-correction		Ey-correction		Ez-correction	
	value [deg]	std.dev. [deg]	value [deg]	std.dev. [deg]	value [deg]	std.dev. [deg]
SC1	0.002468	0.000331	-0.002754	0.000402	0.008868	0.003494

(c) GPS position corrections

GPS-ID	X-correction		Y-correction		Z-correction	
	value [m]	std.dev. [m]	value [m]	std.dev. [m]	value [m]	std.dev. [m]
PC1	0.000	0.0001	0.000	0.0001	0.019	0.0114
PC2	-0.000	0.0001	-0.000	0.0001	-0.050	0.0114
PC3	0.000	0.0001	0.000	0.0001	0.031	0.0114

Figure 3: example of calibration parameters

The statistics in figure 3 indicate an example of some of the corrections made in the system calibration. In addition to the historic calibration corrections, additional validation of the GPS information is performed and evaluated to make sure that with a PDOP of 3 or better the GPS data is usable and has integrity. The figure below (figure 4) indicates the correction of the tie planes.

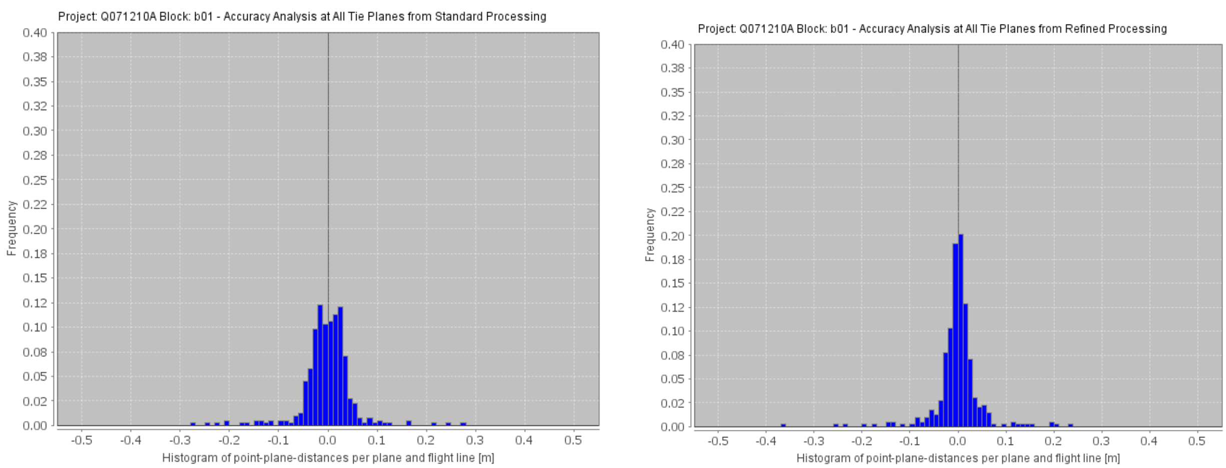


Figure 4: Tie planes before calibration correction and after calibration correction

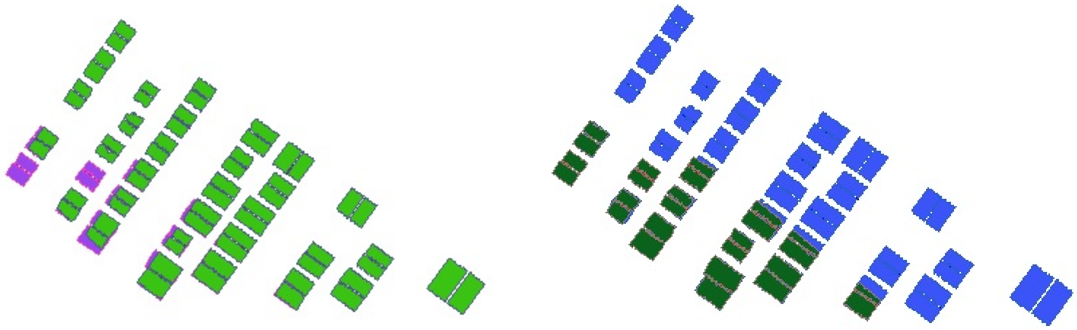


Figure 5: Roof lines prior to calibration correction and after calibration correction

The roof lines are analyzed and corrected in the calibration process as depicted in figure 5 above.

It is imperative that the calibration of the sensor is precise in all aspects of the complexity of the sensor. If the calibration of the system is not exact, then the impact to the collection of the Nebraska project will be significant. The Aero-Metric team understands the importance of calibration and takes major steps to insure the stability of all our sensors.

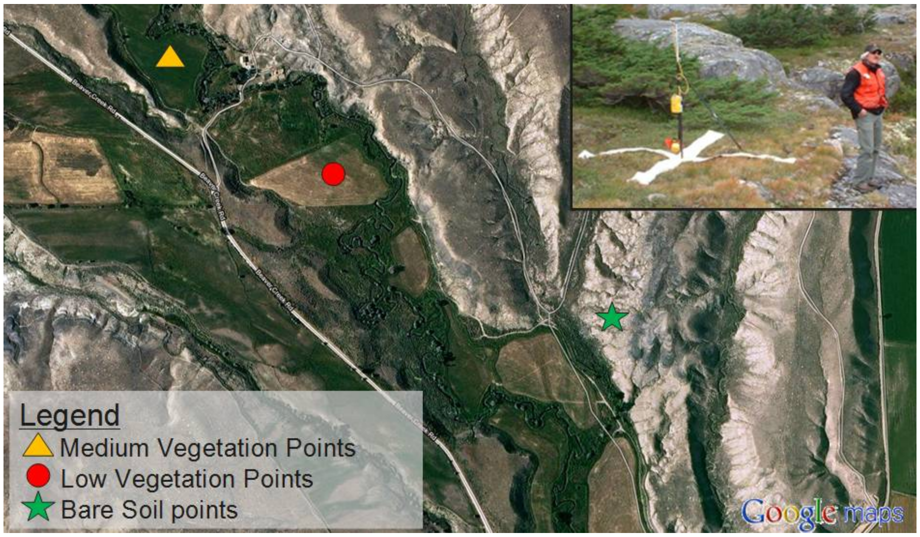
LiDAR In-Situ Data Calibration

In addition to the system calibration, Aero-metric performs project calibrations to further define the system parameters and improve the accuracies as they relate to the project location. During every mission a series of cross flight lines are flown perpendicular to the collection flight lines. This process enables the Aero-Metric LiDAR group to check and analyze the flight line matching and if necessary apply a least squares adjustment to minimize or eliminate flight line differences which will improve the overall accuracy of the LiDAR data. The In-Situ calibration is as extensive as the system calibration and it is preformed on every mission as indicated. The following figure is a representation of an In-Situ calibration for a mission and the same configuration will be utilized on every mission during the collection of the Nebraska LiDAR campaign.

Figure 6: In-Situ Calibration

Planned Control

Aero-Metric has determined 40 check points disturbed throughout the Kittitas LiDAR project location which will be collected to verify the accuracy of the LiDAR collection per the FEMA guidelines and specifications for this project. The following is an example of check point locations and classes to meet FEMA specification.



Ground Check Point Verification

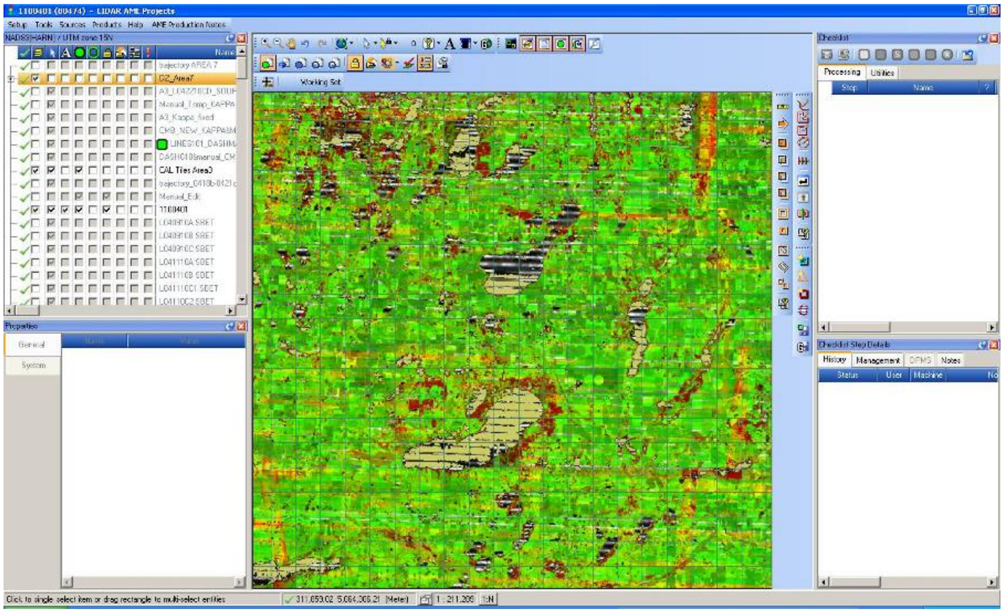
LiDAR QA/QC Procedures

As with all Aero-Metric production processes, extensive QA/QC testing will be applied to the data throughout the work flow. These tests will be designed in the project planning stage to ensure the efficacy of the critical processes necessary to meet final deliverable specifications. Any issues discovered by these QA/QC tests will be immediately addressed to ensure a satisfactory outcome and the generation of deliverables that will meet or exceed all project specifications.

Based on the tiling scheme agreed upon, each tile in the delivery will be examined for compliance with the established specifications. This testing will include, at a minimum, the following:

- Validate proper projection coordinate system and datum
- Verify interpolated elevations from DEM using field-derived blind QA point elevations
- Inspect LAS files for proper format
- Check for disjoints, overlap, or underlap
- Statistically sample files for compliance
- View TIN file and look for spikes
- Validate conformance with intended extent and naming convention
- Verify there is a smooth-edge match with adjacent tiles (slope and elevation)
- Confirm there are no voids in dataset

Aero-Metric employs a variety of methods to provide QA/QC for LiDAR projects. It is our policy to provide multiple QA/QC processes throughout the life of the project. The following are a representative sample of some of the QA/QC procedures used.



DZ ortho Validating Calibration of LiDAR data

Field QA/QC

Aero-Metric QA/QC procedures are designed with the intent that a project is complete the first time, without re-flights. Field QA/QC will consist of several steps to maintain accuracy of our mapping deliverables. When placed in a new platform, the LiDAR unit will be "surveyed in" to provide accurate offset information relating to the GPS and the LiDAR unit. Before starting a project, several test scans will be flown over a fixed object to verify calibration of the operating system. On the day of a survey flight, the flight time will be synchronized with GPS receivers on the ground to ensure a common observation "session." Ground GPS receivers will be set up on the primary control monument at the local airport, which will be free of significant obstructions that may block GPS satellite signals. On-board information displayed on a laptop computer will provide information regarding navigation and overall operation of the LiDAR system, including real-time updates of scan coverage and ranging. Issues with the LiDAR system will be identified immediately while the plane is in flight. Aero-Metric will use multiple ground GPS base stations during a LiDAR survey, increasing redundancy in the data and decreasing the potential of an unrecoverable mishap in data collection. We will maintain a reasonably short distance from the ground GPS stations to the LiDAR system to ensure a fixed-integer solution at all times during the flight. It is our policy to acquire LiDAR only when there is a minimum of six NAVSTAR satellites visible with a positional dilution of precision (PDOP) value below four.

Office QA/QC

Data collected in the field will be processed in an Aero-Metric field office. Several methods will be used to verify the data captured in the field. For example, the instrument height and receiver/antennae combinations will be checked to verify the accuracy of each GPS setup. Field notes will be checked and verified in the office. During the processing phase, all data will be solved using least-squares, which will aid us in identifying and fixing problem data sets. Aero-Metric will confirm that all GPS vectors have achieved fixed-integer solutions. Using proprietary software, we will process the IMU data to verify and validate all roll, pitch, heading, trajectory, and offset measurements. After successful processing, the resulting data will then be independently compared against both the higher-order ground control survey and the precise photogrammetric survey. Further, a system of test patch areas scattered throughout the project, as well as kinematic GPS profiles along area roads to check the validity of the LiDAR data, will be used to validate the LiDAR data. These ground comparisons will be automated, giving statistics indicating the precision and accuracy of the LiDAR mapping. All steps and QA/QC results will be documented in a report.

Procedure for Tracking, Executing, and Checking for Re-flights

Checking Coverage

Aero-Metric plans all missions using a DEM to minimize the potential of gaps in the collection. The DEM is brought into the ALTM_planner software and potential gaps are identified by red. Once this is determined the flight altitude will be adjusted to eliminate the gap and maintain the required point density. The DEM is also used to plan the flights according to terrain and the flight parameters will be adjusted per flight line to account for terrain so we are still optimizing the NPS to meet the USGS NGS specifications required. Although, this usually eliminates the gaps certain flight conditions could exist that potentially cause a gap. The following is the process is used in the field to verify coverage and data usability. The ALTM_NAV software provides an output of the swath coverage and in addition the flight can be brought into Optech's Zinview software if a potential gap is identified.

The GPS and IMU data will be processed to validate the data. This data is combined with the Laser Data and analyzed for usability. The swath data is saved and verified in the field. The data is transmitted to the office of operation on a regular basis and again verified in the office during collection.

Tracking and execution

The tracking of the flights are done using the swath data and log sheets. The log sheets are completed on a mission by mission basis and are tied to the flight plans generated for ALTM_NAV as provided in the flight plan section. The swath data from a previous mission loaded prior to a mission and verify the next line to be flown until all missions for the project are completed. The previous days logs will be referenced as well to verify at all lines are being flown for a project area. All the data will be saved on two separate Disk drives for redundancy to make sure that all data has been transmitted to the office of operation.

Re-flights

In the event that a re-flight is necessary, the line will be identified and logged as a re-flight. The line re-flown will be indicated as such on the flight log so the processing department will know that it is a re-flown line for a specific line.