STARR
Strategic Alliance for Risk Reduction

Quinnipiac

Pre-Flight Operations Plan

November 2010

Planned Flight Lines

Photo Science has completed preliminary flight planning for Quinnipiac project area. Quinnipiac is scheduled to be acquired this fall when the leaves are off and delivered to FEMA in late spring of 2011. The Quinnipiac area is 443 square miles and initial planning details are depicted in Figure 1 on the following page. This Figure details that STARR expects to collect **93 flight lines covering 1136 flight line miles**. This area warranted a "Highest" vertical accuracy requirement and will be collected with a nominal pulse spacing of 1-meter. Key components of this flight planning include:

- ✓ Generating a plan that takes all specifications into account, and the required Laser settings to meet those specs, review of terrain and water issues, along with potential base station locations at airports with sufficient services available to support the crews.
- ✓ Orientation of flight lines parallel to major terrain features and variation in flight line spacing due to terrain variation (steeper slopes generally require tighter line spacing between adjacent parallel lines to ensure point density and side overlap are maintained)
- ✓ Check Airspace issues, and access issues for Base Stations.
- ✓ Safety considerations, both for flights, and Laser collection.

Acquisition (443 sq. miles @ 1-meter nominal post spacing to meet 24.5 cm FVA, LAS point cloud delivery with metadata, pre-operations flight plan, and post flight aerial acquisition report).

Planned GPS Stations

Normally existing high accuracy monuments at airports are utilized if possible. Typically a Primary Airport Control Monument (or Secondary) is available; otherwise any other high accuracy monument can be used. We typically prefer these on the airport grounds as they can be monitored for security by airport staff. If no monument is available or an existing monument is damaged, we will set a monument with re-bar and use OPUS to control the monument. These are then used for initial field processing of the data.

Planned Control

Twenty-one (21) ground control points will be surveyed to control the LiDAR data and to support a vertical test. Each of these two functions shall remain independent of each other and also be collected by an independent subcontractor (CompassData). Independent check or calibration points will be three times as accurate as the surface being checked. Therefore, in order to validate a 24.5 cm LiDAR surface (consistent with 2 foot contours), STARR will collect elevation control data accurate to 8 cm. This "three times" model for collecting ground control and QA points will be used throughout the task order.

Vertical accuracy checkpoints will be located by another independent STARR contractor (CompassData) to check Photo Science's work in open terrain, where there is a high probability that the sensor will have detected the ground surface without influence from surrounding vegetation. Checkpoints will be located on flat or uniformly sloping terrain and will be at least five (5) meters away from any break line where there is a change in slope. This criterion applies for all QA points for the Fundamental Vertical Accuracy (FVA) Assessment as well.

Blind vertical QA points for the Consolidated Accuracy Check (CVA) will also be collected by CompassData to check Photo Science's work randomly across different land use types using the ASPRS NSSDA land cover types. The points will be located in flat areas with no substantial elevation breaks within a 3-5 meter radius. We expect to normally pick one area and get 3-5 different land use classes from a single setup. We expect to normally use GPS to position an occupation and backsight point and then use a total station to get the other classes from that setup. The CVA assessment will incorporate a representative sample of the FVA assessment into the dataset to save on the total number of points collected. Figure 1 below has a location map of the flight lines and ground control points.

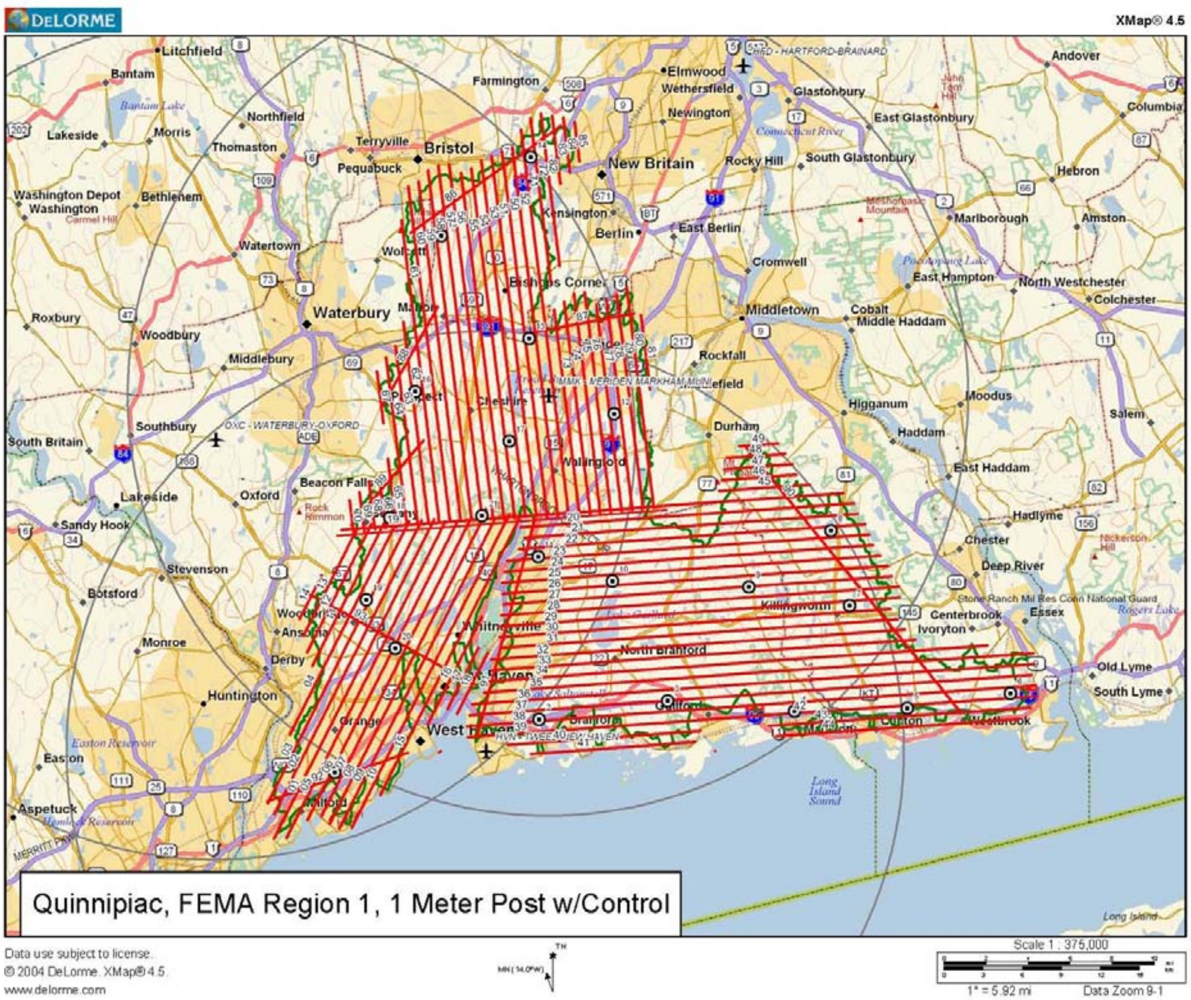

Figure 1-Quinnipiac Flight Lines, Ground Control, and Airport Locations

Planned Airport Locations

Photo Science will be utilizing two airports for Quinnipiac for mobilization and demobilization. As indicated in Figure 1 the two airports will be MMK - Meriden Markham and HVN Tweed New Haven. All base stations used during flights are based at these Airports

Calibration Plans

Periodic detailed boresighting of the LiDAR sensor is performed at a boresight facility established in Lexington, Kentucky for both our LiDAR and imagery platforms. Over 95 high-accuracy control points are located within this facility. The area also has numerous pitched roofs that are necessary in boresighting LiDAR instruments. Local boresights are also carried out at individual project sites. Typically these are established at local airports and consist of opposing and cross flights conducted at multiple flight elevations. The boresight data is processed by our Lead LiDAR Specialist with the results for all boresight parameters applied to the project acquisition. Figure 2 below outlines some of the basic principles that Photo Sciences conducts for LiDAR boresighting.

Figure2

Sensor Calibration Boresighting
✦ Photo Science routinely performs a Comprehensive Calibration process from our permanent boresighting location at the Capital City Airport in Frankfort, KY, as well as daily, local project specific boresighting locations.
✦ Photo Science established GPS survey points for LiDAR ground truthing and reflective survey analysis.
✦ Our calibration methodology adheres to the basic survey principle of *"working for the whole of the parts"* ensuring that residual values of the calibration are reduced, *not* multiplied.
✦ Photo Science calibration process validates roll, pitch, heading, pitch at swath edge, and torsion.

Calibration – all of our sensors are calibrated by flying lines at multiple altitudes and at varying directions over features on land, typically at the airport where the acquisition is staged. These lines are used to remove angular errors between the IMU and scanning mirror and to determine the precise positioning of the sensor in relationship with the phase center of the GPS antenna mounted on the fuselage of the aircraft.

Calibration of the Elevation Surface – the raw LiDAR surface is compared against ground points that are established for the calibration of the elevation surface. System biases are identified and removed during this calibration. An early statistical analysis takes place that provides an indication of the precision of the acquired data.

Additionally, each lift requires a cross flight over the lines collected during that flight. This also acts as a daily calibration and is used if any anomalies are discovered with processed data.

Quality Control Procedures for Flight Crew

Acquisition Crews

An experienced and knowledgeable acquisition crew is also critical to a successful LiDAR project. We will bring two capable crews to the project site with three more in reserve should any unexpected health issues or similar complications arise.

General Flight Mission Procedures

On a lift by lift basis the flight crew will check cloud conditions, atmospheric conditions (fog or probability of fog) and winds and turbulence. If any of those factors would make acquisition difficult they will wait a few hours and review again.

LiDAR crews can fly at night or during the day. Night flights can be smoother in some cases, but extra care must be used as it is easy to lose orientation with the ground if in very rural areas or over large expanses of water. Additionally, if there are fog probabilities then flights will not take place as fog will block the laser. It must be clear below the aircraft at all times.

The initial item is to set the base station properly over the monument, verify it is secure and running. Prior to setting the crew will have ascertained that it has storage space on the hard drives and full battery life. They will also verify that it is running with proper collection parameters. PDOP is also reviewed as collection will not take place during times of high PDOP.

The LiDAR system (controller hard drives and Laser) is connected to the flight management system and once the project plan is loaded the parameters for collection will load as well. The sensor operator will verify that everything loaded correctly before flight.

Once the LiDAR has been started the crew will taxi to the run up area and wait for the IMU, GPS and the rest of the system level out. They will collect data in a stationary position for about 5-10 minutes until the POS (position and orientation system) provides good level characteristics (Green Lights!).

After this they crew will take off and start collection data, avoiding hard steep turns (banks typically <20 degrees). Collection requires that speeds be maintained, sometimes quite slow depending on the accuracy requirements. Additionally altitudes must be watched closely.

During flights the sensor operator must monitor the laser to sure that temperatures are consistent and within guidelines, that pulsing is taking place correctly and returns are consistent and within guidelines while watching atmospheric conditions, speeds and monitoring the pilot.

Planned ScanSet (Laser Collection Parameters)

Parameters	15cm RMSE, 1m
Flying Height	5000
Aircraft Ground Speed (knots)	94
Pulse Rate (KHz)	143.7
Scan Rate (Hz)	48.3
Full Field of View (degrees)	34
Multi-Pulse	Yes
Full Swath Width (meters)	844/961
Swath Overlap (percentage)	30%
Max. Point Spacing Across Track (meters)	1.0
Max. Point Spacing Along Track (meters)	1.0
Across Track/Along Track Ratio	1.0
Average Point Density (M2)	3.10
Average Point Area (M2)	.32
Average Point Spacing (Meters)	.57
Nadir Point Density (pts/m2)	2.00
Illuminated Foot Print Diameter (meters)	.35

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Type of Aircraft

All of our LiDAR sensors are currently flown in specially modified single-engine Cessna 206 platforms. This platform provides a very stable platform for LiDAR data acquisition, with the ability to easily achieve altitudes and speeds that are most common for LiDAR collection. Achieving an accurate, dense posting of LiDAR returns on the ground is most often associated with altitudes of 2,000 to 7,000 feet above the average terrain height at speeds ranging from 90 to 140 knots. These ranges are ideal for this single-engine platform.

Our platforms also have significant fuel capacity, which allows us considerable time over target for performing data collection. It is also a safe platform, which is important when flying over rugged terrain. The added bonus is this is a very economical platform to fly in terms of operational and maintenance costs. Moreover, that translates to competitive rates for LiDAR data acquisition.

Aircraft Name	Engine Configuration	ABGPS	Flight Management System	Ceiling Feet
Cessna U-206G	Single	Yes	Yes	16,700
Cessna U-206G	Single	Yes	Yes	16,700
Cessna U-206H	Single	Yes	Yes	15,700
Cessna U-206H	Single	Yes	Yes	15,700

Procedure for Tracking, Executing, and Checking Re-flights

All daily flights are tracked with specific logs for each area. These include general logs indicating the lines, date flown etc. as well as very specific mission logs concerning the lift, weather conditions, times, speeds and other criteria critical to the performance of the laser. The daily flight logs are faxed to the office on a daily basis and entered into an access database for tracking purposes. This helps determine where next to move crews and overall project status.

After flight each day, the GPS ground base station data is processed and verified and is then is run against the LiDAR POS data in both a forward and reverse sense. The two solutions are then compared against one another for all GPS epochs and the individual differences for the northing, easting, and elevation components are plotted for easy comparison. This data is then run against the LiDAR returns and a point cloud generated. Any anomalies in the data are quickly analyzed, and if required, re-flights take place for the portions of the flight missions that require remediation.

Once the data is checked it is archived, backed up and a set sent to the office via overnight delivery, while the backup copy remains with the crew.

The flight crews do not leave the area of collection until all data has been verified and shipped.

Considerations for Terrain, Cover, and Weather

Terrain is not an issue for flight planning on this project. The area is very flat. Cover has been considered and collection is scheduled for the Fall of 2010 during leaf-off conditions. Traditional LiDAR weather conditions will be observed for this area.