Mission Planning Details

The following outline provides a description of the procedures, system overview, personnel, and timeline associated with the WVDEP LiDAR campaign over the Southern Coalfields of West Virginia.

Project setup
1. A meeting was held on 10 December 2009 (0830) at NRAC to discuss the mission’s logistics, priority areas, personnel, equipment, time tables, and deliverables.
2. NRAC’s project manager will develop internal, project-specific documentation as a reference for the production staff. This Project Summary outlines the scope of work, project specifications, deliverables, project schedule, technical procedures, and the quality assurance plan.
3. NRAC prepares its production facility for the project. The primary tasks that are integrated in preparation of beginning the project are:
   - Scheduling of resources (equipment and personnel)
   - Customizing in-house software tools, as necessary
   - Customizing Quality Control checklists for each department specific to the project
4. A project of this magnitude requires a start-up period of approximately two weeks. Additional time is needed for specific waivers and authorization. Once the information is gathered and/or tested, the team is ready to begin the next step of the project.

Survey new ground control
NRAC will establish 30 new ground control points throughout the project area. These ground control points, in conjunction with Airborne GPS control, will support the accuracy requirements of the project. NRAC proposes to target and survey all new ground control points. The intent of this new control is for the support of this project only, and permanent monumentation is not being proposed. All new monuments will be collected via Real-Time Kinematic Surveys, which are points in reference to already established NRAC proposes the use of conventional ground Global Positioning Systems (GPS) techniques to establish the primary control locations. Static, Rapid Static, and Kinematic GPS techniques shall be incorporated for the points required to complete the mapping.

LIDAR SYSTEM DESCRIPTION
1. NRAC operates an OPTECH ALTM-3100C airborne laser mapping system. The system integrates a scanning laser Altimeter, a high-end Applanix Pos/AV Intertial Measurement Unit (IMU), also called an Intertial Navigation System (INS), and a dual frequency Trimble GPS receiver. The system offers several user-configurable parameters that allow the data capture campaign to be tailored to each specific project. This integrated system is capable of 100kHz operation.
LiDAR technology offers fast, real-time collection of three-dimensional points that are employed in the creation of Digital Elevation Models (DEMs) and other desired deliverables.

2. In-flight data are logged to hard drives, which provides for immediate extraction and viewing of post-mission data. Data quality, coverage, and other mission critical information are reviewed immediately to determine if re-flights are necessary. Basic parameters of NRAC’s LiDAR system include:

<table>
<thead>
<tr>
<th>OPTECH ALTM-3100 LiDAR</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Altitude</td>
<td>80-3500 meters nominal</td>
</tr>
<tr>
<td>Horizontal Accuracy</td>
<td>1/2000 x altitude, 10</td>
</tr>
<tr>
<td>Elevation Accuracy</td>
<td>&lt;15cm @ 1200m; 10</td>
</tr>
<tr>
<td>Range Resolution</td>
<td>1cm</td>
</tr>
<tr>
<td>Range Capture</td>
<td>Up to 4 range measurements for each pulse</td>
</tr>
<tr>
<td>Intensity Capture</td>
<td>12-bit dynamic range for each measurement</td>
</tr>
<tr>
<td>Scan Frequency</td>
<td>Variable; maximum 76 Hz</td>
</tr>
<tr>
<td>Scan Angle</td>
<td>Variable from 0 to 25°; in increments of 1°</td>
</tr>
<tr>
<td>Swath width</td>
<td>Variable; 0 to 0.93 x altitude (m)</td>
</tr>
</tbody>
</table>

Flight plans are based off of submitted geometry provided by the client. Each plan is optimized for efficiency and complete coverage. During acquisition, the aircraft passes over the base stations to assure that ‘on-the-fly’ integers are correctly fixed during post-processing and then proceeds to fly the project in parallel strips. The strips overlapped each adjacent flightline by a sufficient amount (30%) to ensure complete coverage of the project area. The aircraft typically maintains an airspeed of 135 knots (155 MPH) at a prescribed altitude. In turns, the aircraft bank angle is limited to 20 degrees whenever possible to avoid loss of lock on GPS satellites.

NRAC takes careful planning for ground collection to ensure baseline lengths and PDOP (Positional Dilution of Precision) are not exceeded beyond tolerable limits. Each station occupied must be of GPS quality and high stability as determined by rigorous standards set forth by the National Geodetic Survey. NRAC also uses the WV CORS and NGS’ OPUS (Online Positioning User’s Service) to download/create GPS monuments (respectively) and constantly monitors baseline length and applicable elevation masks to ensure the highest quality data. NRAC used the following locations for GPS observations during the WV DEP Tug Project:

<table>
<thead>
<tr>
<th>PID/Name</th>
<th>Lat. (DMS)</th>
<th>W Long (DMS)</th>
<th>E UTM (M) (n)</th>
<th>N UTM (M) (n)</th>
<th>Elev. (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logan Airport</td>
<td>37 11.46.588</td>
<td>81 16.44.498</td>
<td>419937.463</td>
<td>419024.135</td>
<td>302.430</td>
</tr>
<tr>
<td>Welsh Airport</td>
<td>37 21.22.225</td>
<td>81 11.36.1566</td>
<td>414142.763</td>
<td>414803.305</td>
<td>446.530</td>
</tr>
<tr>
<td>H.D. Bailey Lake</td>
<td>37 35.49.6699</td>
<td>81 10.14.0414</td>
<td>427543.200</td>
<td>414127.742</td>
<td>426.685</td>
</tr>
<tr>
<td>Mingo Airport</td>
<td>37 41.16.55310</td>
<td>82 15.35.05030</td>
<td>386938.242</td>
<td>417056.376</td>
<td>454.885</td>
</tr>
<tr>
<td>Mercer Airport</td>
<td>37 12.29.45012</td>
<td>81 11.39.24305</td>
<td>411315.952</td>
<td>412732.134</td>
<td>501.987</td>
</tr>
<tr>
<td>A5540</td>
<td>37 16.32.39.275</td>
<td>81 1.31.40.933</td>
<td>49075.200</td>
<td>4187560.626</td>
<td>264.136</td>
</tr>
</tbody>
</table>

* All heights are orthometric (NAVD88 - North America 1988 Vertical Datum)
1. **Optech ALTM-3100 LiDAR Sensor**: The sensor was calibrated over the Morgantown Airport (KMGW) on 22July2010 before data was collected in the Tug Watershed. The calibration report is provided below:

[CALIBRATION]

AltimSerialNo=04SEN165  
ImuType=LN200A1  
ImuRate=200  
ScannerScale=1.007317  
ScannerOffset=0.007000  
IMURoll=-0.017248  
IMUPitch=-0.019217  
IMUHeading=0.033001  
UserToImuEx=-0.010000  
UserToImuEy=0.060000  
UserToImuEz=0.000000  
UserToImuDx=-0.090000  
UserToImuDy=-0.008000  
UserToImuDz=-0.096000  
UserToRefDx=-0.051000  
UserToRefDy=-0.030000  
UserToRefDz=-0.488000  
TimeLag=0.00017750  
IntensityGainFor3070=20.000000  
UseLeftDroopCorrection=15.000000  
UseRightDroopCorrection=15.000000  
Temperature=29.000000  
Pressure=984.000000  
meteoCorrMethod=1

[INTENSITY]

IntensityTable33Khz=R:  
IntensityTable50Khz=R:  
IntensityTable70Khz=R:  
IntensityTable100Khz=R:  
IntensityTable125Khz=R:  
IntensityTable142Khz=R:  
IntensityTable166Khz=R:

[RangeOffset33KHz]

LastPulseRange=-2.370000  
FirstPulseRange=-2.370000  
SecondPulseRange=-2.370000  
ThirdPulseRange=-2.370000

[RangeOffset50KHz]

LastPulseRange=-2.350000  
FirstPulseRange=-2.350000  
SecondPulseRange=-2.350000  
ThirdPulseRange=-2.350000

[RangeOffset70KHz]

LastPulseRange=-2.360000  
FirstPulseRange=-2.360000  
SecondPulseRange=-2.360000  
ThirdPulseRange=-2.360000

[RangeOffset100KHz]

LastPulseRange=-2.320000  
FirstPulseRange=-2.320000  
SecondPulseRange=-2.320000  
ThirdPulseRange=-2.320000

[RangeOffset125KHz]

LastPulseRange=-0.000000  
FirstPulseRange=-0.000000  
SecondPulseRange=0.000000  
ThirdPulseRange=0.000000

[RangeOffset142KHz]

LastPulseRange=0.000000  
FirstPulseRange=0.000000  
SecondPulseRange=0.000000  
ThirdPulseRange=0.000000

[RangeOffset166KHz]

LastPulseRange=0.000000  
FirstPulseRange=0.000000  
SecondPulseRange=0.000000  
ThirdPulseRange=0.000000

[ScannerPolynomialCoefficients]

DegreeOfPoly=1  
a0=0.000000000000000  
a1=0.000000000000000

[AtmosphericFilter]

WindowSizePoints=15  
ThresholdMeters=50.000000  
FilterType=0  
OpticalModel

BEAM0_PITCH=0.000000  
BEAM0_ROLL=0.000000  
BEAM1_PITCH=0.000000  
BEAM1_ROLL=0.000000  
DIx=0.000000  
DIy=0.000000  
DIz=0.000000

MIRROR_PITCH=0.000000  
MIRROR_ROLL=0.000000

CrystalFreq=100.000000  
CrystalResolution=50.000000
2. **Topcon HiPER GD GPS Receivers**: Geodetic, dual-frequency, highly-accurate GPS receivers were calibrated over established monuments certified for GPS quality by the NOAA National Geodetic Survey (NGS). Specifically, the two units were based over Permanent Identification Description (PID) AA9268 and an OPUS (Online Positional User Service) point established at the WVU Agricultural Sciences Building.

### POST-PROCESSING OF MULTIPLE RETURN DATA

1. NRAC uses several significant process steps to filter (classify) data for project specific map accuracies ranging from 1’ to 5’ contour intervals. Each step takes the data to sufficient levels for the level of accuracy and processing required. These steps may be modified based on project requirements including but not limited to, map accuracy, terrain, and canopy morphology (i.e. urban, heavy or multiple canopy vegetation, water, and swamps).

2. Data is most often classified by ground and canopy, but specific project applications can include classifications of multiple return data types including by not limited to buildings, stratified vegetation, power lines, etc. This is a very labor-intensive process and is generally not recommended on contour only projects. Typical deliverables for contour datasets are generally limited to include canopy and ground surfaces only.

3. In general practice, these workflow steps include:
   - **Step 1**: Differentially post-process the LiDAR aircraft’s GPS and IMU with known ground GPS coordinates to create a ‘smooth best estimate of trajectory’
   - **Step 2**: Fuse together range data with SBET to generate 3-dimensional point clouds
   - **Step 3**: Automated filtering based on terrain variables

### QUALITY CONTROL AND ASSURANCE MEASURES AND PROCEDURES

1. Post-flight: At the conclusion of each lift, the LiDAR drives are removed from the aircraft, downloaded (POS and range data) [Optech Software, ‘Disk Extract’], decimated for a more manageable and time-efficient check [Optech Software ‘Zinview’], and resulting swath data is checked for gaps, slivers, and other anomalies. Voids are further examined and reflown if necessary.

2. RTK Survey: Real-Time Kinematic Surveys were completed
PERSONNEL

Jerald J. Fletcher, Director, Natural Resource Analysis Center
Paul J. Kinder, Research Scientist, Natural Resource Analysis Center
Michael G. Metz, GIS Specialist, Natural Resource Analysis Center
Adam C. Riley, GIS Analyst, Natural Resource Analysis Center