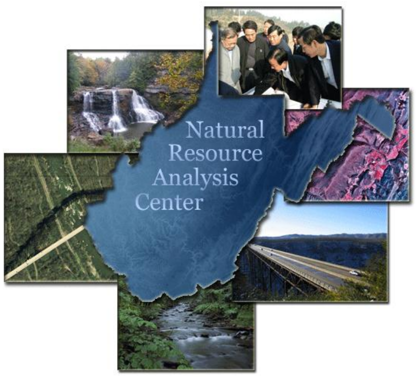



## Mission Planning Details

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 10December2009 (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.

***Establishing Non-intrusive ground control points on the WVU Evansdale Campus***

*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

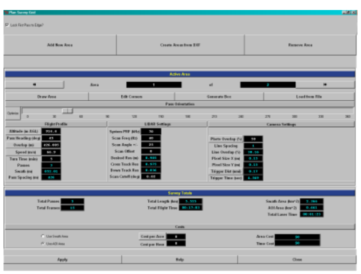
*The OPTECH ALTM-3100*

at an operating height of 1,100 meters (3,609 feet). 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:

| OPTECH ALTM-3100 LiDAR | |
|---|---|
| Operating Altitude | 80-3500 meters nominal |
| Horizontal Accuracy | 1/2000 x altitude; 1ó |
| Elevation Accuracy | <15cm @ 1200m; 1 ó |
| Range Resolution | 1cm |
| Range Capture | Up to 4 range measurements for each pulse |
| Intensity Capture | 12-bit dynamic range for each measurement |
| Scan Frequency | Variable; maximum 70 Hz |
| Scan Angle | Variable from 0 to 25°; in increments of 1° |
| Swath width | Variable; 0 to 0.93 x altitude (m) |

## FLIGHT PLANNING



*Specific deliverables allows NRAC to set flight parameters*

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.

## GROUND PLANNING

*Dual-frequency 20-channel GPS receivers enable NRAC to ensure horizontal and vertical accuracy of all LiDAR points*

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:

| PID/Name | Lat. (DMS) | W Long (DMS) | E (UTM 17N) (m) | N (UTM 17N) (m) | Elev (m)* |
|---|---|---|---|---|---|
| Logan Airport | 37 51 23.74954 | 81 54 36.44198 | 419937.463 | 4190294.615 | 502.439 |
| Welch Airport | 37 25 7.02225 | 81 31 36.15568 | 453393.418 | 4141442.763 | 644.310 |
| R.D. Bailey Lake | 37 35 49.46699 | 81 49 14.84114 | 427543.766 | 4161427.742 | 426.685 |
| Mingo Airport | 37 41 16.55310 | 82 15 30.59850 | 389038.242 | 4171936.376 | 454.880 |
| Mercer Airport | 37 17 29.43612 | 81 12 38.74705 | 481318.952 | 4127232.14 | 867.987 |
| AA9348 | 37 46 52.78278 | 81 7 25.40555 | 489105.206 | 4181560.626 | 764.126 |
| * *All heights are orthometric (NAVD88/Geoid09)* | | | | | |

## EQUIPMENT CALIBRATION

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]

AltmSerialNo=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

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IntensityTable50Khz=R:\Fall_DEP_data_DEP_Fall_Data\Fall_DEP_folders\lidar_proc\dashmap\HWCONFIG\50Khz intensity.txt
IntensityTable70Khz=R:\Fall_DEP_data_DEP_Fall_Data\Fall_DEP_folders\lidar_proc\dashmap\HWCONFIG\70Khz intensity.txt
IntensityTable100Khz=R:\Fall_DEP_data_DEP_Fall_Data\Fall_DEP_folders\lidar_proc\dashmap\HWCONFIG\100Khz intensity.txt

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SecondPulseRange=-2.370000
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a1=0.000000000000000
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ThresholdMeters=50.000000
FilterType=0
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BEAM0_ROLL=0.000000
DX0=0.000000
DY0=0.000000
DZ0=0.000000
MIRROR_PITCH=0.000000
WINDOW_PITCH=0.000000
WINDOW_YAW=0.000000
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CrystalFreq=100.000000
CrystalResolution=50.000000

DegreeOfPoly=-1

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

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